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Fuzzy Based Fast Detection of Short Circuit Current in PV Distributed Generator

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ABSTRACT

This paper proposes a novel fast short circuit current detection technique for PV inverter based distributed system. The PV system is used to stabilize a critical load. Here the fuzzy logic is used to detect the occurrence of short circuit current. It can be read the value of voltage and current to detect the fault. Through MATLAB simulation of the distribution system is demonstrated to response successfully regardless of the type of fault and the location of fault on the distribution system. The proposed short circuit current detector is based on the evaluation of slope and magnitude of PV inverter current. As soon as it detects a fault that is likely to cause the PV inverter short circuit current to exceed the rated current of the inverter, it can do either Disconnect the PV inverter, so that it does not cause any adverse short circuit current injection into the system (here the load is disconnected from the source) or Automatically, transform the PV inverter into dynamic reactive power compensator STATCOM (termed as PV STATCOM) to provide voltage support.

I. INTRODUCTION

In electric power systems, integration of more Distributed Generators (DGs) in the network increases the short circuit level due to the short circuit current contribution of the DGs during faults. Compared to the synchronous and induction machine based generators the inverter based generators, such as Photovoltaic (PV) solar systems, contribute lower fault current to the network due to the characteristics of PV panels and inverter operation. The short circuit current contribution from a PV system inverter is typically in the range of 1.2 times rated current for the large size inverter (1MW), 1.5 times (500kW) for medium size inverter and between 2 - 3 times for smaller inverters. Although, each PV solar farm may contribute short circuit currents as above, the total amount of fault current contribution may become unacceptably large for a feeder, which has several PV systems connected. It is apprehended that short circuit current contributions from multiple solar systems in the distribution feeders may add up to levels that could be damaging to the circuit breakers. Hence circuit breakers will need to be upgraded and substations will need to be modified at significant cost to the utility. The objective was to prevent the loss of opportunity to integrate more PV based renewable generation in the distribution systems.

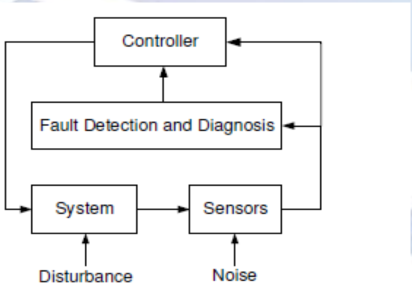
It is required to disconnect the PV solar farms or any other DGs upon detection of fault on the system, grid codes require the DG inverters to stay connected and provide Low Voltage Ride Through (LVRT) capability during fault scenarios. It is therefore important to detect the faults rapidly, and either disconnect the DGs from the network or provide grid support functions e.g. LVRT, as quickly as possible, depending upon the prevalent grid code requirements. The fuzzy logic system hasthe ability to detect the fault in power system.

The work found the fuzzy system could read the value of voltage and current to detect if there is a fault or not. Through MATLAB simulation of the distribution system is new controller is demonstrated to response successfully regardless of the type of fault and the location of fault on the distribution system. The objective of this technique is to facilitate PV solar farm in obtaining permission to get connected in substations of feeders. This technique is general and can be applied on a PV solar system connected in any grid network.

II FAULT DETECTION METHODS

2.1. Fault Detection Without Using Fuzzy:

The subject of a FDD system has been the focus of many investigations. Different invasive and noninvasive methods have been reported, for incipient and permanent fault detection in different disciplines such as electrical, mechanical, chemical engineering. Noninvasive methods are based on measuring the system condition by only analyzing information obtained outside theequipment, such as terminal and environmental measurements. Often, due to legacy nature or the added cost of complicated internal sensor arrangements, noninvasive techniques are more economical and preferred. In general, the development of a FDD system involves a time consuming process to identify the symptoms to be monitored, providing the correct signals for recognition of suitable fault symptoms, and then providing the correct computational methods to de-correlate the signals into time-based residuals. Usually, the detection schemes and the parameter settings developed are very specific to the system under investigation.



Fault detection methods can be further grouped into:

1) Model Based;
2) Knowledge Based; And
3) Signal Based.

2.2. Fault Detection Methods Using Fuzzy:

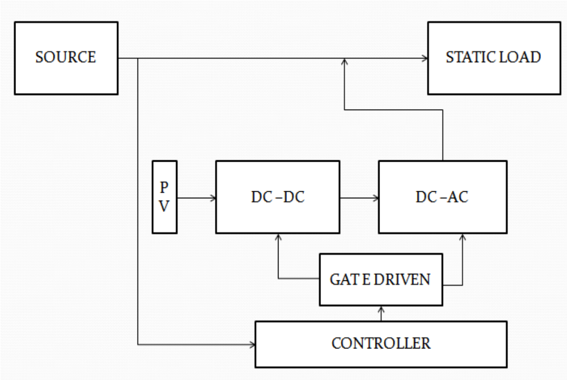
This system presents a new fast short circuit current detection technique based on the rate of rise of current together with the current magnitude in a PV solar system based DG, deriving its concepts from the patent . The short circuit current is detected very rapidly and any of thefollowing two control operations can be initiated, per the applicable grid code in that region

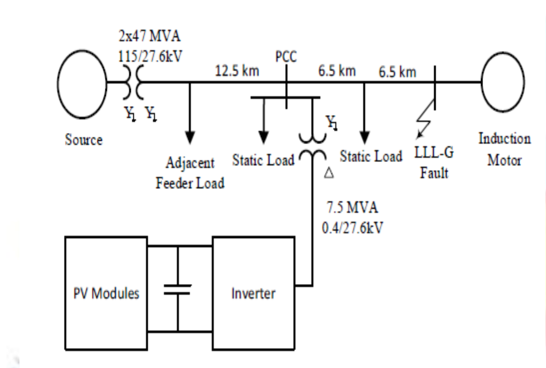
i) *disconnect*the PV inverter before the current exceeds the rated output current of the inverter. This rapid disconnection of DG prevents the fault current to rise beyond the utility permissible limits. Implementation of such a strategy potentially alleviates the problem of short circuit currents from PV solar systems which led to the delay or denial of their connectivity. It is emphasized that the objective of the proposed technique is not to detect the occurrence of any fault in the network but only to identify such fault conditions during which the inverter short circuit current is likely to exceed its rated magnitude. The intent is todisconnect the inverter as rapidly as possible, as soon it is predicted that the short circuitcurrentwillreach limits considered unacceptable by the interconnecting utility.

ii) *Transform* the PV inverter into a dynamic reactive power compensator STATCOM and provide grid support functions. A new concept of utilizing PV solar farms as STATCOM (PV-STATCOM) both during nighttime and daytime for different grid support functions was introduced in These functions include dynamic voltage support to increase the connectivity of neighboring wind farms, enhance power transmission capacity through power oscillation damping, etc. The short circuit current detection technique proposed in this paper can be utilized to shut down the real power generating function of the PV solar farm very rapidly in the event of a fault, and autonomously transform the PV solar farm into a STATCOM (PV-STATCOM) with full inverter capacity. This smart inverter control concepts is based in part on the pending patent

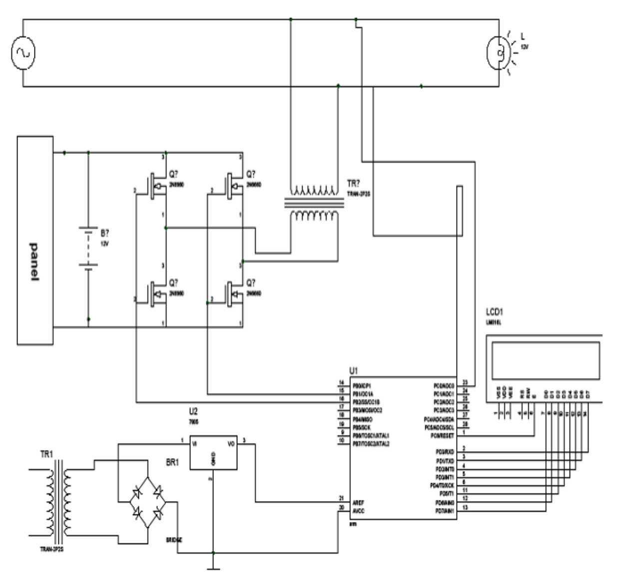
In this a case study is presented when a fault in the network causes a critical inductor motor load to get destabilized. Shutdown of these critical IM loads, even for a short duration of few minutes, can result in significant economic loss to the industrial facility using these IMs as the entire batch of materials being transported/served by these motors may get damaged. The proposed technique does not disconnect the PV inverter. Instead it transforms autonomously and rapidly the PV solar inverter into a STATCOM and helps stabilize this critical induction motor load.

2.3. Block Diagram:



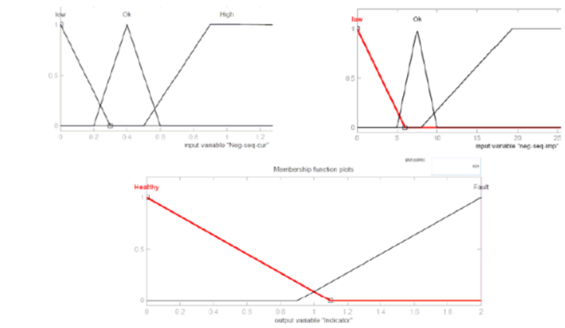


2.4. Circuit Diagram:



III FUZZY LOGIC BASED FAULT DETECTION

The fuzzy logic system developed here provides a robust and sensitive detection mechanism of stator winding short circuits in a PMSM under load fluctuations. The robustness of the fault detection system is exhibited consistently and accurately detects the fault under the most demanding conditions, such as load fluctuation. The sensitivity is manifested in the capacity of judging and discriminating between an incipient fault and healthy load fluctuation condition. The detection process is accomplished using a fuzzy logic system with a fuzzy membership function module. This membership module provides a qualitative heuristic interpretation of the filtered negative sequence current and the negative sequence impedance based on expert knowledge. Trapezoidal membership functions are used with variable overlap. These fuzzy heuristics serve to build the universe of discourse *X* and *Y* for each of the input spaces of negative sequence current and negative sequence impedance magnitudes. The universe of discourse represents the inputs' range of operation. Figure 4.7 shows plots of the implemented membership functions for negative sequence current, negative sequence impedance, and



Membership function plots of negative sequence current, negative sequence impedance and output functions.

output indicator, respectively. These configurations are based on the observation of the system under different grades of severity of stator winding faults and load fluctuation operation. The membership functions established are only valid for the system studied. The values for negative sequence current under normalconditions depends on factors such as inherent unbalance due to the construction or assembly of the machine, asymmetry in the instruments, etc. In addition, the values of negative sequence impedance are particular to each motor for each point of operation. Therefore, the system proposed mustbe adjusted for each different machine.

The fuzzy rule module provides the antecedent-consequence statements of fuzzy logic. These statements provide the condition of the fault being monitored given the linguistic operating range of inputs. The fuzzy rules represent a combination of the qualitative heuristic knowledge of the system and the quantitative description of the motor conditions. The consequence provide the quantitative information about the motor usin the descriptions of healthy (Normal) and faul (Alarm). The implication operator used in the fuzz inference system is based on Mamdani's form an is constituted by five conjunctive rules as th membership functions, these rules are formulate based on the experience and a meticulou observation of the behavior exhibited by th machine under fault and healthy conditions. Th defuzzification process is performing using th Centroid method. The simplest membershi functions are formed using straight lines. The triangle membership is a collection of three points forming a triangle. The trapezoidal membership function has a flat top and is a truncated triangle curve. These straight line membership functions have the advantage of simplicity and are used in this approach. This membership module provides a qualitative heuristic interpretation of the filtered negative sequence current and the negative sequence impedance based on expert knowledge.

IV SIMULATION CIRCUIT DIAGRAM

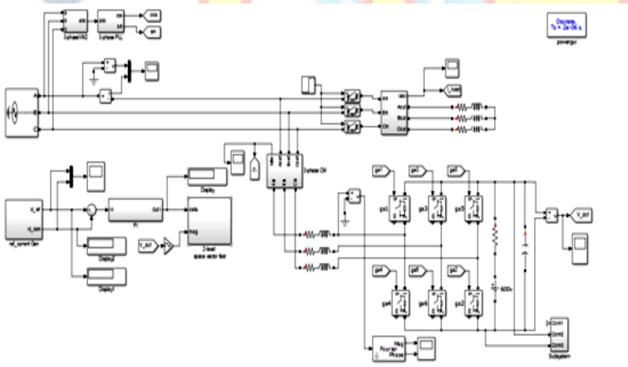
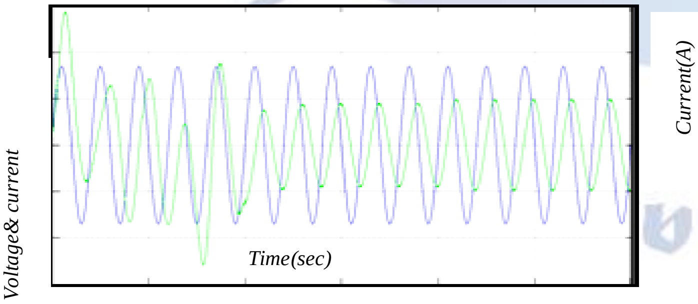


Fig 4.1Circuit Diagram with fuzzy logic controller

4.1 SIMULATION WAVEFORM:



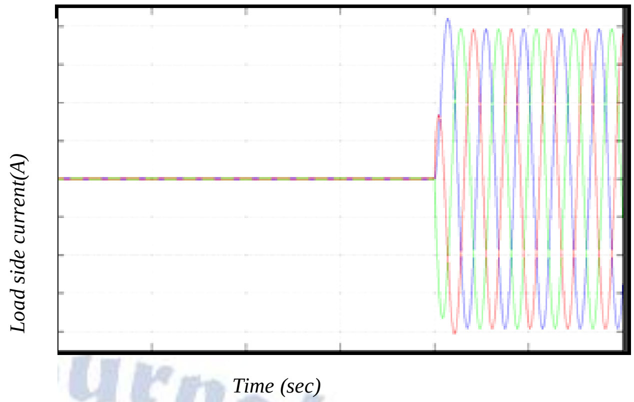


Fig 4.2 Voltage & current waveform

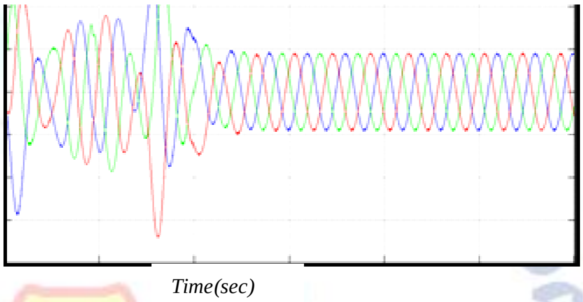


Fig 4.3 current wave from PV system

V CONCLUSION

In this paper, a novel fast short circuit current detection technique is proposed for PV inverter based DGs.. As soon as it detects a fault that is likely to cause the PV inverter short circuit current to exceed the rated current of the inverter.The entire process of DG disconnection or transformation into a PV-STATCOM from the instant of fault detection typically takes about 1.5 millisecond.. This technique is general and can be applied on a PV solar system connected in any grid network. The application of this short circuit current technique has been demonstrated to shut down PV solar farms so as not to contribute any short circuit current into the grid. The objective of this technique is to facilitate PV solar farms in obtaining permission to get connected in substations or feeders which have already reached their short circuit current limits without the apprehension of additional short circuit current contribution from these solar farms. However, in regions where LVRT is a requirement, this technique is also beneficial for a faster initiation of grid support functions by the PV inverter.

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