Analysis and Enhancement of FRT Capability for a Grid Tied PV System with ANN and ANFIS Controller

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Abstract: **This paper defines a ANN and ANFIS based Voltage source converter (VSC) is proposed. This can used for reduce the power oscillation and current variations during grid fault conditions. Distributed sources are isolated from grid during different conditions (1) increment in dc link voltage; (2) Drastically change in current more than rated and (3) synchronization failure. The single and two stage inverters are used to address the fault. The ANN and ANFIS based controller is used to compensate the reactive power under grid fault conditions to enhance fault ride through capacity of the system. The proposed ANN and AMFIS controllers will increases fault ride through capability of system compared to conventional PI controller.**

Index Terms— ***High-frequency transformer (HFT), indirect modulation, leakage commutation, matrix converter, PWM AC drive, solid-state transformer.***

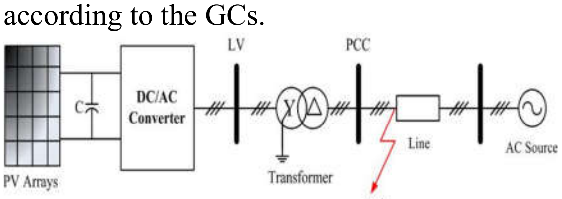
I. INTRODUCTION

The short circuit current in power systems is still dominated by classical synchronous generators of conventional large scale coal or nuclear power plants. As a result of the ever increasing share of renewable energy sources the short circuit current in the future will differ from the status quo. The fast control of the power electronics in wind and photovoltaic power conversion systems has the capability to control the current injection during balanced as well as unbalanced grid faults. Large scale photovoltaic (PV) systems are one part of the efforts to increase the share of renewable energy sources in the energy mix. Different configurations are available to feed in power to the grid. By contrast large scale PV units are connected to the medium or even to the high voltage network using central inverters. As a consequence large scale PV systems affect the power flow in the interconnected network and so they have to fulfill certain requirements regarding their electrical properties which are usually described in grid codes. Fault Studies are important in large-scale grid connected renewable energy systems and have been reported in the technical literature. However, most of these studies focused on grid-connected wind power plants. In the case of grid-connected photovoltaic (PV) power plants (GCPPPs), research reported thus far focused on fault-ride through (FRT) capability. Specifically, a three-phase current-source inverter (CSI) configuration was investigated under various fault conditions, in which the output currents remain limited under all types of faults due to the implementation of a current-source model for the inverter. However, this configuration may lead to instability under dynamic conditions. Three-phase voltage source inverters (VSIs) are used in grid-connected power

conversion systems.
Due to the increasing number of these systems, the control of the VSIs is required to operate and support the grid based on the grid codes (GCs) during voltage disturbances and unbalanced conditions. Considering FRT strategies for grid-connected VSIs, some research has been done on wind turbine applications and also on VSI-based high-voltage direct current (HVDC) systems. Some of these studies are based on passive control, e.g., crowbar and chopper resistors, whereas others are based on active control schemes. Although both categories can provide FRT capability, the passive methods have the drawbacks of requiring additional components and dissipating significant power during the voltage sag processes. In the application of GCPPPs with the configurations of single-stage conversion (single-stage conversion means direct connection of the PV source to the dc side of the VSI), some research were done to evaluating the FRT issues of both ac and dc sides of the inverter under unbalanced voltage conditions.

APPLICATION OF CONTROL STRATEGIES

A 1-MVA single-stage GCPPP is considered. It is modeled using MATLAB/Simulink and the system main specifications are summarized from the data given and Fig. 4.3(a) shows the model of the GCPPP. In concerning the FRT capability, the inverter disconnection factors are illustrated according to the GCs.



. **Fig-1** Schematic Diagram of Single Stage GCPPP

The problems stated in this paper are explained by considering voltage sag with balanced and unbalanced faults. To meet the fault ride through, at first dq current references, namely i_{dref} and i_{qref} are calculated from dc-link voltage control and Droop control respectively, which is shown in fig-2. These reference values can be modified according to the FRT (fault-ride-through) for control the inverter.

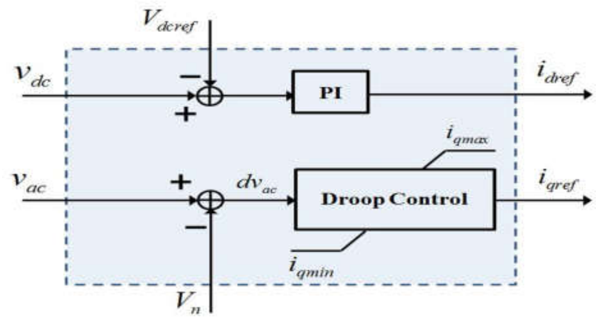


Fig-2: Representation of i_q and i_d references

The problem of inverter disconnection from grid was explained by considering the faults in the system on the given above figure 2.

PI control with anti-windup technique:

In case of anti windup technique, the control technique same as PI control but taking of integral part into consideration is done according to the error in the system as shown in fig-4.3.1.2.

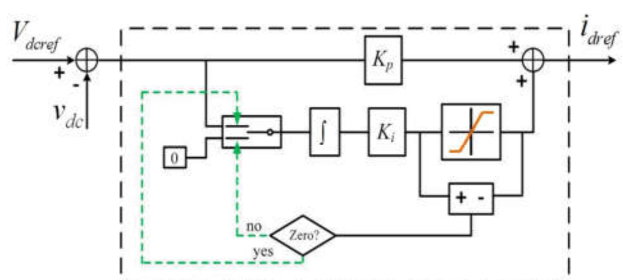


Fig-3: control diagram of PI with anti-windup technique

The resulted system waveforms because of anti windup technique are shown in Chpter-5.

Artificial neural network Artificial neural network (ANN) can be considered as massively parallel distributed processing systems with the potential for ever-improving performance through dynamical learning. They allow non-algonthmic information processing, i.e.,
no "programming" is required as in more conventional algorithmic signal processing. The ultimate object of artificial neural network is to closely simulate the function of the human neural system. Indeed multi-layered networks have been shown to develop very similar structures to existing human physiological structures with no human interaction or guidance. Also, the development of fast architectures makes implementation m real time feasible unlike artificial intelligence techniques which are infamous for their lengthy computation times. One the objectives of intelligent control is to design a system with acceptable performance characteristics over a very wide range of uncertainty The system must be robust enough to deal with unexpected occurrences, large parameter variations, unquantified data, or extremely large quantities of data. Besides the approaches of expert systems and fuzzy logic, an increasingly popular approach is to augment control systems with artificial neural networks. An artificial neural network (ANN) is a system consisting of simple processing elements called "units" or "nodes" that interact using weighted connections. It can interact with its environment, and it may be capable of learning. A neural network can be defined by its processing behaviour, its interface to the environment, its structure, and its learning procedure. The processing behaviour of an artificial neural network is defined by the computations performed by its units and their temporal coordination. Generally, a unit calculates three functions: an input function producing the unit's input value; an 4 activation function producing the unit's activation value; and an output function producing the unit's output value. In most neural network models only one function called "transfer function" is assumed to be equal for all units. In the case of stochastic transfer functions the output of an unit depends on the unit's input in a probabilistic fashion, and changing the weights means changing the probability of the output values.

II. **Application** ANFIS controller design

Adaptive neuro-fuzzy technique (or Adaptive neuro-fuzzy inference controlling system, ANFIS) has been suitably involved in the designing of Fuzzy inference system (FIS). In this context, the designing has been accomplished with sugeno type technique that lines out the input characteristics to input membership functions. Fuzzy inference is applicable to only modeling system whose structure is virtually designed by the users perception of the variable characteristics modeled in the inference system is as shown in fig.3. In some sort of designing conditions it may not be easy to analyze the data of the membership functions it should be more correlate with the membership function promptly. A network-type design same as neural network system has been adopted to strengthen and improvise the input/output map such a way that it is ample to measure the input units through the pre mentioned membership functions of input/output parameters that are correlated with the membership functions which can be altered through the learning procedure. In the process of calculation, the variable parameter changes are supplemented with a gradient vector, which has been used as reference to the FIS to measure the input/output data in correspondence with the pre-determined parameters.

The controller takes measured values as a inputs to due particular task. To maintain DFIG synchronism with grid, the voltage, phase angle and frequency same for this two. This can be achieving by comparing measure values with references. The measured DFIG voltages and currents are compared with references, then the error between this two and change in error taken as a input to ANFIS controller. ANFIS can reduce error in two stages one is rule base action. In this case the ANFIS can check error value range based on this output can generate with a range closer to reference, and then this output is given to trained system. Farther the error is reduced based on this trained parameters, it will make the system outputs closer to references.

e/Δe	NB	NM	NS	Z	PS	PM	PS
NB	NB	NB	NB	NB	NM	Z	Z
NM	NB	NB	NB	NM	PS	PS	Z
NS	NB	NB	NM	NM	Z	PM	PM
Z	NM	NM	Z	Z	Z	PM	PB
PS	NM	NB	PB	PM	PB	PB	PB
PM	NB	PB	PB	PM	PB	PB	PB
PB	Z	PB	PM	PB	PB	PB	PB

II. RESULTS

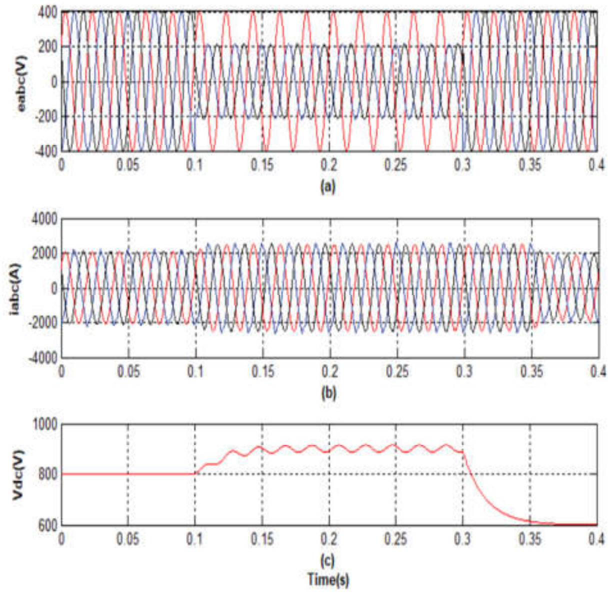


Fig 5 (a) Short-circuit in the PV Panel (a) Grid Voltage (b) Grid Current (c) dc-link Voltage at 0.1 to 0.3 sec supplying 60% SLG voltage sag at MV Side of the Transformer

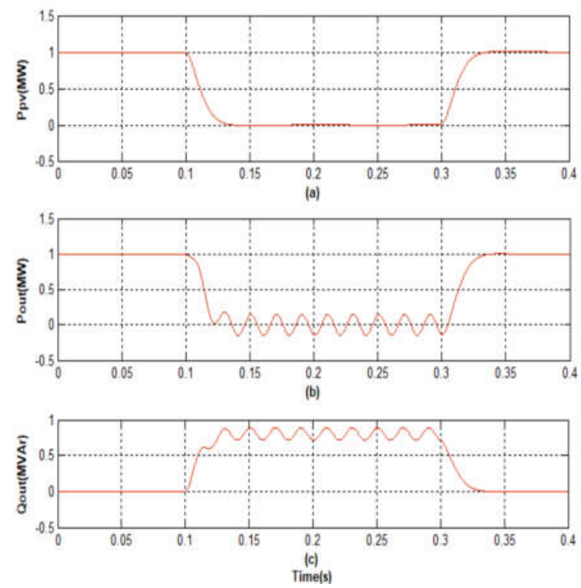


Fig. 6.short circuiting the PV panels (a) overall generated power; (b) injected active power; (c) reactive power to the grid

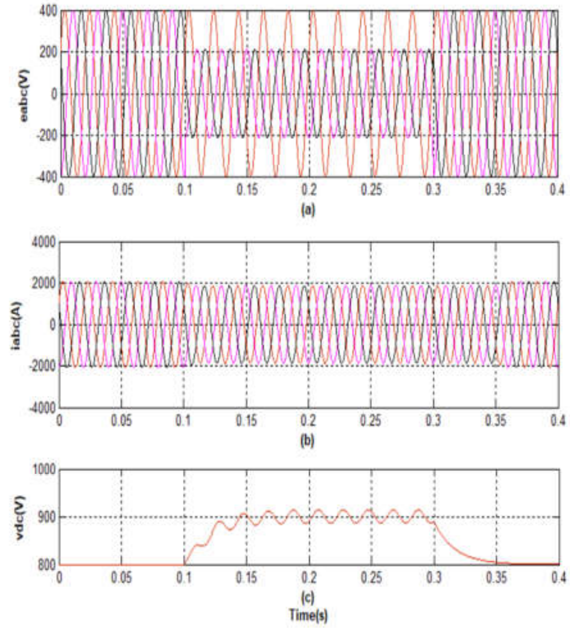
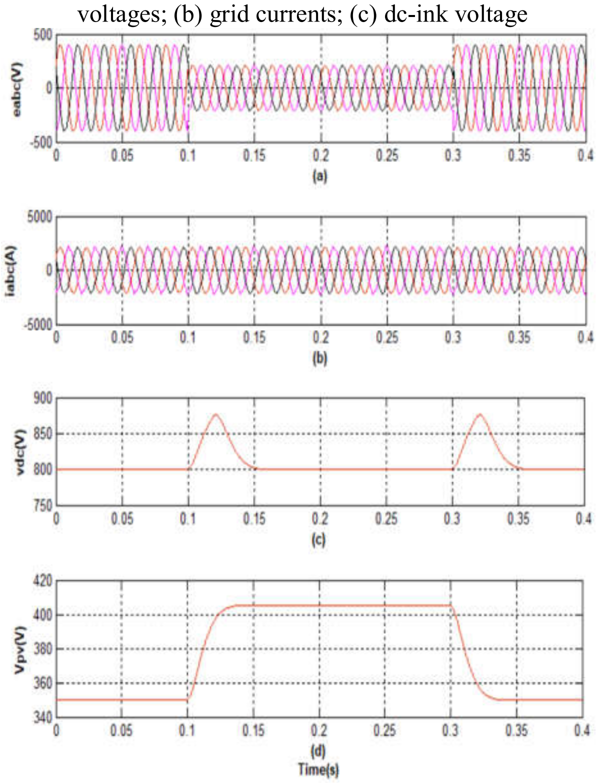
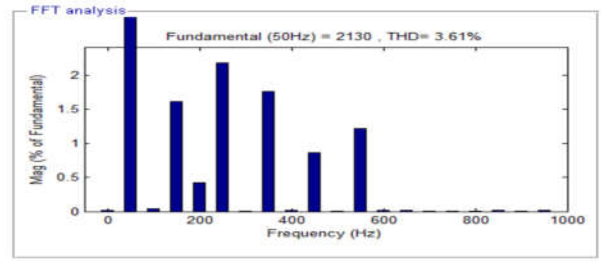


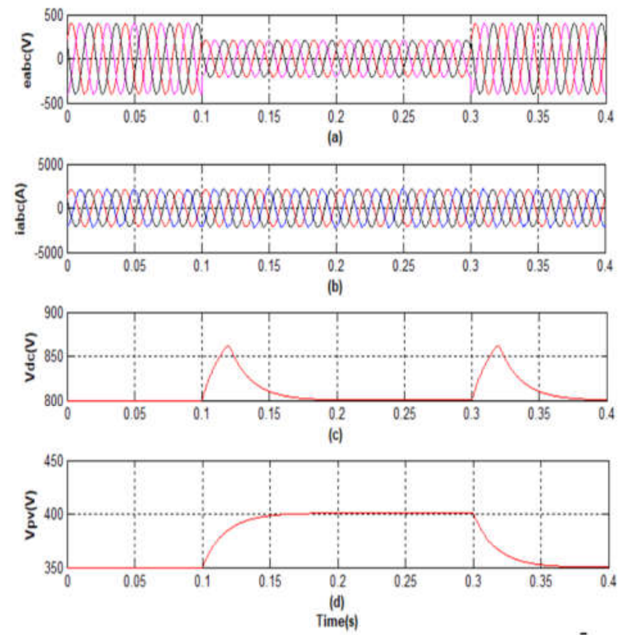
Fig. 8. Turning the dc-dc converter switch ON: (a) grid voltages; (b) grid currents; (c) dc-ink voltage

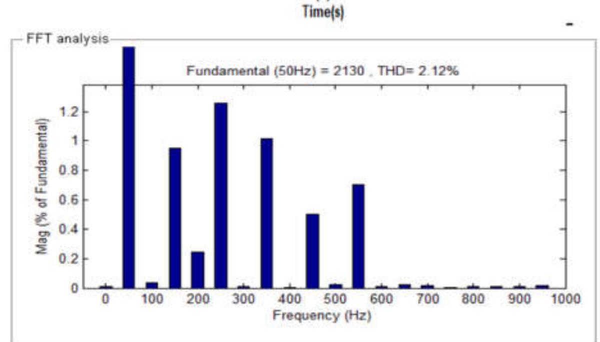




(e)

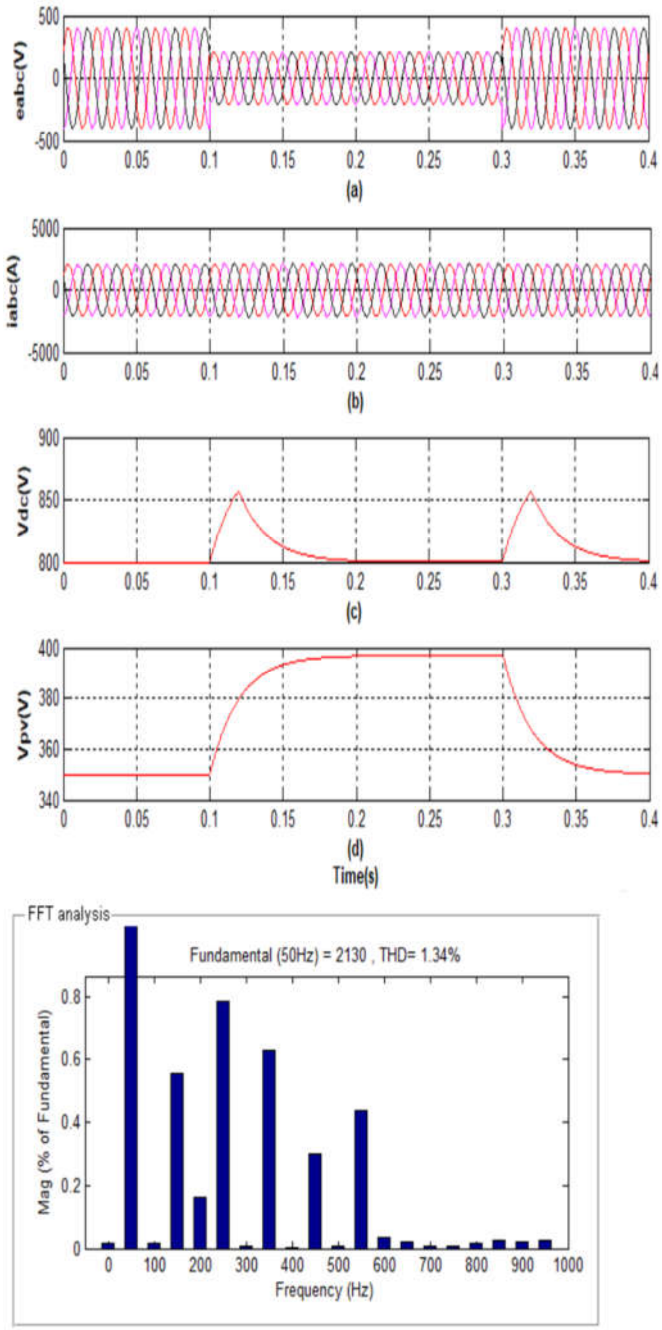
Fig. 11. Control of dc-dc converter to produce less power under voltage sag (a) grid voltages; (b) grid currents; (c) dc-link voltage; (d) input voltage of the dc- dc converter under a 3LG with 45% voltage sag at MV side of the transformer (e) Current harmonic spectrum.





(e)

Fig. 13. Control of dc-dc converter using ANN to produce less power under a voltage sag (a) grid voltages; (b) grid currents; (c) dc-link voltage & (d) input voltage to dc-dc converter (e) Current harmonic spectrum.



(e)

Fig. 14. Control of dc-dc converter using ANFIS to produce less power under a voltage sag (a) grid voltages; (b) grid currents; (c) dc-link voltage & (d) input voltage to dc-dc converter (e) Current harmonic spectrum.

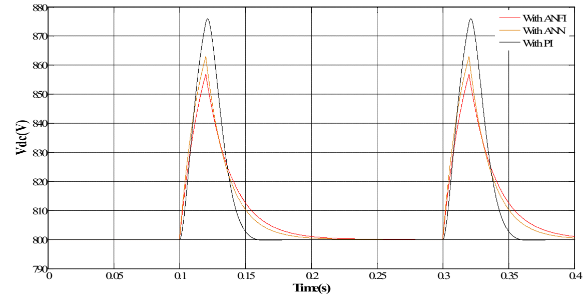


Fig. 15. Comparison of dc-link voltage using PI, ANN, ANFIS

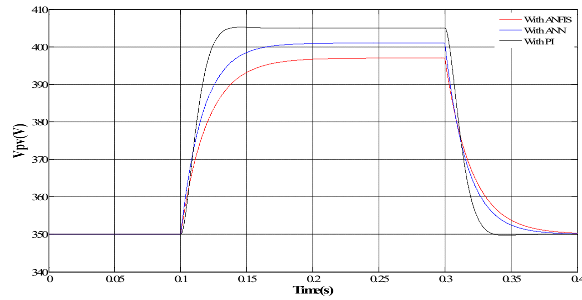


Fig. 16. Comparison of input voltage to dc-dc converter using PI, ANN, ANFIS

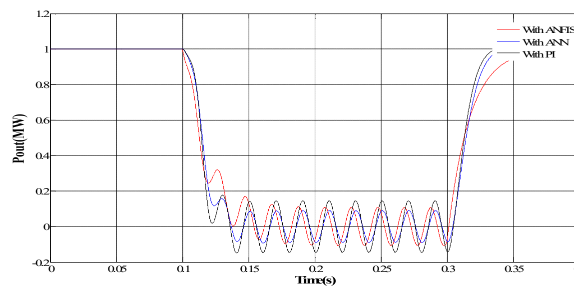


Fig. 17. Comparison of real power using PI, ANN, ANFIS

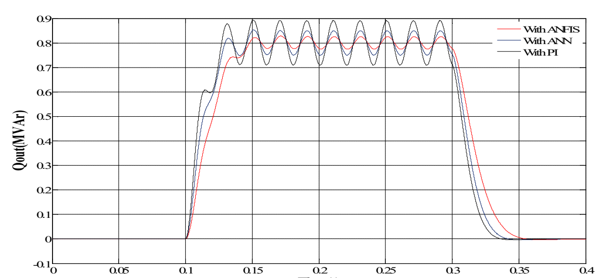


Fig. 18. Comparison of reactive power using PI, ANN, ANFIS

Table. 2. THD values using different controlling techniques.

Controlling technique	PI	ANN	ANFIS
THD (CURRENT)	3.61%	2.07%	1.34%

III. CONCLUSION

In this thesis, the issues of Single and two Stage Grid Connected Photovoltaic Power Plant are specified. Control strategies are given to make the system ride through for specified issues without disconnection of inverter from the grid. The fault through capability over different faults was explained by means of Proportional & Integral controller (PI), ann and anfis controller. The improved grid currents and other parameters are specified after implementation of control strategies. The performance of PI, ANN and ANFIS based controllers are used to compensate the reactive power under grid fault conditions to enhance fault ride through capacity of the system. The analyzing the simulation results of proposed controllers based system will increases fault ride through capability of system compared to conventional PI controller.

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