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RESEARCH ARTICLE

Fault Detection and Troubleshooting in a PV Grid-Tied Inverter

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Abstract

Objectives: Present work envisages fault detection along with troubleshooting methodologies confirmed in solar photovoltaic workshop for grid-tied three-phase inverters. Only innovative inventions are not only necessary for the society to become advanced but also to continue the modern electrical evolution with zero carbon. **Methods:** Here with the help of sungrow software DSP1_20_VA_J & IDM- AC Fm ver the inverter sends a notification about the fault with a fault status code to the HMU/LCD display. As per fault severity it may completely shut down or partially operate the inverter with reduced load. After the fault rectification manually by the site operator again it restores the power and inject power to the grid. **Finding:** Here with the help of sungrow software DSP1_20_VA_J &IDM- AC Fm ver we find various types of faults with the nature of faults i.e. insulation fault, leakage current fault, over voltage/under voltage fault, frequency faults, temperature fault, islanding with its rectification process. The major, minor, and cautionary faults and their troubleshooting procedures are elucidated in the present study with coding of faults, and its alarm level. **Novelty:** In previous researches, the fault identification was not done properly; as a result the inverters are tripping frequently. The present software helps to detect fault of the inverter within 0.023 millisecond and send a message to the service engineer for rectification. The present research can be of immense help to the service engineers and field workers working on solar photo voltaic sector considering popularity of photovoltaic units.

Keywords: Solar power plant; Grid tied inverters; Fault finding; Trouble shooting

1 Introduction

A solar photovoltaic (SPV) system alters the solar light energy into electrical energy. The SPV system comprised of solar panel(s), charge controller (CCR) or inverter,

battery bank (optional), electrical and mechanical appliances[1–3]. The energy produced is either stored in a battery bank in an off-grid system or fed to the grid for supply through an on-grid or grid-tie technology. Inverters act as a brain of any SPV system. The grid-tie inverter alters direct current (DC) into a required alternating current (AC) for adding into an electrical power grid[4]. Other inverter application includes; wind turbines and micro turbines, variable frequency drives, High voltage direct current (HVDC) power transmission and uninterruptable power supply.

Modern inverters use solid state designs with microprocessor control to produce high quality AC power very efficiently[5–8]. To feed electrical power competently and securely into the grid, grid-tie inverters must be synchronized with the healthy voltage, frequency and phase of the grid. Grid-tie inverters are also aimed to quickly detach from the grid if the utility grid become unserviceable. The grid tie inverter shuts down to prevent the energy it transfers from harming any line workers working on the power grid[9–13].

In the present work, Sun grow make inverter with capacity 3125 kW has been used having maximum input voltage 1500 V with maximum power point tracker (MPPT) voltage range from 875-1300 V[14–17]. Maximum AC output power is 3125 kW at 50-degree temperature. This inverter is installed at 20MWp Gavhankund solar project, Maharashtra.

2 Overview of a Grid Connected SPV System

On-grid solar power plant is one in which the power plant is fed with grid through transmission line. In on-grid solar power plant a DC power is generates through photo voltaic solar module[6,18]. With the help of grid tied inverter, DC power is converted in to AC power then routed to the nearby grid where the power is supplied for use, demonstrated in Figure 1.

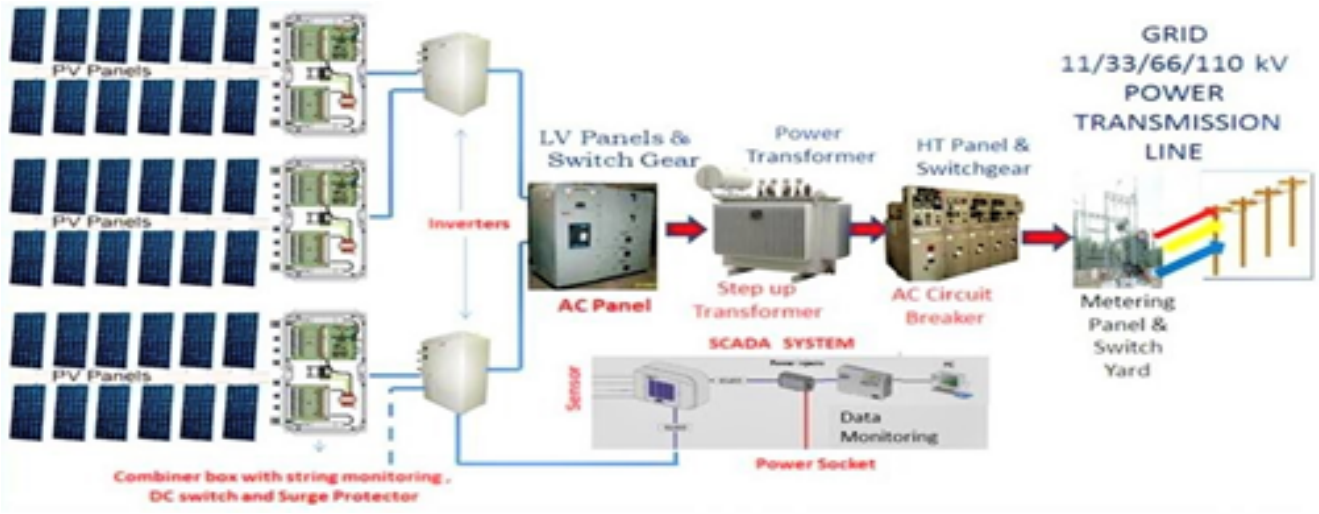

Fig 1. The stage diagram of a grid connected solar power plant

Installation of solar power plants has been gained momentum on a large scale for the last decade. Most of the countries with large economy are now constructing large scale (>20 MW) solar plants to fulfill the rising energy demand and carbon emission drop in the environment[19]. PV industry is still working on the safe operation of these PV plants and developing products to prevent the several plant faults arising in grid set up demonstrated in Table 1.

Table 1. Different types of high efficiency grid tied solar inverters

Manufacturer Name	Capacity (KW)	Europe efficiency %	Maximum efficiency %
Sungrow Power Supply Ltd	3125	98.7	99.0
Sinengelectric Co ltd	3125	98.7	99.0
ABB Ltd	1000	98.2	98.64
Schneider Electric	2000	98.5	98.8
TMEIC	3125	98.2	98.5
DELTA	3125	99.0	99.2

In this article we have taken Sun grow inverter with capacity 3125 kW having maximum input voltage 1500 V with MPPT voltage range from 875-1300 V [20,21]. Maximum AC output power is 3125 kW at 50-degree temperature. This inverter is installed at 20 MWp, Gavhankund solar project, Maharashtra.

3 Methods and Materials

Indian renewable energy sector is the fourth most eye-catching renewable energy marketplace in the world. Till November 2020 the installed capacity of renewable energy up to 90 GW. In an On-Grid solar power plant inverter plays an important role as it converts the DC power generates from module to the electrical grid in AC form [22–24]. Those faults have been identified, and mainly categorized are: 1. Major Faults, 2. Minor Faults, and 3. Warning Faults.

3.1 Major Faults

This fault will shut down the inverter and stops feeding power in to the grid. In minor faults some components of the inverter are faulty but the inverter can still feed the power to grid. Function of the inverter is normal, but the output of power drops due to external factor [25–27].

Individually the faults are identified in the photovoltaic workshop on the basis of laboratory fault finding observations and corrective actions are reported for attending using the His-Fault software (DSP1_20_VA_J &IDM- AC Fm ver) and the results are as follows: (Table 2 and Figure 2(a) to Figure 2(h)).

Table 2. Various major faults with its troubleshooting in a Grid-tied inverter

Fault Code	Fault explanation	Measures for fault rectification
Driver board		Check whether the AC/DC side of module is short-circuited Check whether the grid is normal
Center- fault	Contactor faulty	Check all AC and DC contactor appearance.
Mism-lac	AC current is unbalanced	Check whether the grid is normal or phase loss occurs.
L over -temp	Reactor temperature is excessively high	Check the present ambient temperature is within the permissible range. Check the inverter air inlets are not obstructed. Check the grid voltage whether harmonics is normal.
Vdc-low	DC voltage is excessively low	Check all DC connection properly. Check DC voltage in display.
Bus-under voltage	Bus voltage is excessively low	Check all DC connection properly. Check DC voltage in display.
Temp-fault	Temperature is excessively high	Check the present ambient temperature is within the permissible range. Check the inverter air inlets are not obstructed. Check the cooling fans whether operating or not.
Vac-high	Grid voltage is higher than the set	Disconnect all AC switches and measure the AC voltage In stop mode check the inverter voltage in display unit. Maintain the grid voltage as required by transformer tap changing if any.
F-fault	Grid frequency is abnormal	In the stop mode; check the inverter freq. in display unit. Check whether the protection parameter satisfies the local standards and regulations.
Vac-low	Grid voltage is lower than the set	Disconnect all AC switches and measure the AC voltage. In stop mode check the inverter voltage in display unit. Maintain the grid voltage as required by transformer tap changing if any.
Island-No grid	Grid blackout	Check whether the grid is normal. Check whether the power outage occurs on AC side. Check whether the AC current breakers of the module are connected.
Control power sup- fault	Control supply is abnormal	Check all control supply switches; be in ON position. Check whether the external and internal power supply terminals are loose or poorly connected. Fasten the terminal properly.

Continued on next page

Table 2 continued

DC/AC-SPD fault	SPD on DC side is faulty	Check the SPD colour. Red is indicates for SPD damage. If SPD is in normal colour (green), then check any poor contacts between terminals. Check whether the micro circuit breaker connected in series to the SPD is disconnected.
I leakage	Sampling value of AC leakage current above set value	Check whether the AC cables are damaged. If the LV side of the transformer is connected in Y type, ensure that the neutral point is unconnected.
Gnd-flt	Grounding faults	Check whether the DC cables are damaged. Check all the insulation of AC cables. Check whether the voltages to ground of all the three phases are the same or not. Check whether the SPDs on the inverter side and transformer side are damaged.

3.1.1 Various fault detection by DSP1_20_VA_J &IDM- AC Fm ver

In the laboratory the various results obtained due to various major faults are demonstrated in Figure 2(a) toFigure 2(h).

Fig 2. (a). Drive board fault, (b). Grid AC current imbalance, (c). Grid AC current imbalance fault, (d). High Temperature Faults, (e). No grid fault, (f). Surge Protective Devices (SPD), (g). I-Leakage fault, (h). Fan fault

3.2 Minor Faults

In the minor fault, some components are faulty, but the inverter is still operative to feed power into grid. Few minor faults which rises in a megawatt scale grid tied inverter are as follows; (Table 3 and Figure 3).

Table 3. Summary of various minor faults with its troubleshooting in a Grid-tied inverter

Fault Code	Fault explanation	Measures for fault rectification
External power supply	External power supply is abnormal	1. Measure the external power supply voltage with a multimeter to check whether the voltage is within the normal range. 2. Check if there are any poor contacts. 3. Check all connected switches ON/OFF conditions.
Branch breaker fault	Circuit breaker on DC branch circuits are abnormal	1. Checked whether the branch circuit breaker is closed or not. 2. Check the control supply to the circuit breaker. 3. Check the circuit breaker run-information on the screen of the LCD.
CT Unbalanced-fault	3-phase grid current is unbalanced	1. Check whether the AC three-phase current is in balance.
Meter-Com Fault	short- circuit between control boards and metering board	1. Locate the fault and rectify
T & H Communication Fault	Error between temperature and humidity board	1. Locate and rectify

3.2.1 Breaker fault detection by DSP1_20_VA_J &IDM- AC Fm ver

Fig 3. Breaker fault by the software DSP1_20_VA_J & IDM- ACFm ver

3.3 Warning Faults

Warning faults are those in which the inverter function is normal but the output power drops due to external factors. These type of cautionary faults do not make the circuit unserviceable or breakdown but must be attended [28,29]. These major warning faults are (1) Grid Fault Ride Through (GFRT) Run, (2) Volt shift in volt ampere reactive (VAR), (3) Frequency shift watt adjusted; HVRT: high voltage ride-through (Table 4 and Figure 4).

Table 4. Summary of various warning faults with its troubleshooting in a Grid-tied inverter

Fault Code	Fault explanation	Measures for fault rectification
Frequency shift Watt adjective	Active power of inverter is adjusted ac to change in grid	1.Check, via the LCD, whether the over frequency derating function is enabled. 2.If the function is enabled, it indicates over-frequency occurs during the operation.
GFRT run	Grid fault occurs, the inverter can ride through the time	1 .Check whether the grid voltage exceeds the HVRT or LVRT threshold.
Volt shift Var adj	The reactive power of the inverter is adjusted according to the change of the grid voltage.	1. Check whether the "Q-adjust switch" is in the "QU mode".
Encoding repeat	The main cause of the encoding repeat fault is addresses of the interior modules are repeated.	1. This is a major inverter fault we have to contact manufacture immediately.
Carrier Synch Fault	The main cause of the carrier synch fault is due to the abnormal of carrier signal transmission.	1. A major inverter fault which may be attended immediately with the help of inverter manufacturer.

3.3.1. GFRT Run

Fig 4. GFRT fault by thesoftware DSP1_20_VA_J & IDM- AC Fm ver

In this present work we have studied various types of faults associated with solar grid connected inverters with its rectification methods. Here we investigate the fault and attempt the troubleshooting of various grid connected inverters. When a fault occurs in a solar inverter we are unable to pump power to the grid as a result we face power interrupted with huge amount of revenue losses. If any fault occurs due to any reason like over voltage, temperature, or insulation failure or the fault between ground and the short circuit caused by low insulation resistance may lead to electric fire, device damaged or even physical hazards. Hence, power supply and quick power restoration.

4 Gavhankund Solar Power Plant (Similar Project)

The installation capacity of 20 MWp/16 MW AC capacity this plant is located at Gavhankund, Amaravati, Maharashtra, latitude -21.50° N, 78.20° E [30,31]. With an average solar irradiation 6 kWh/m2 this plant export more than 95000 kWh/day to MAHAGENCO grid with life span of 25 years' and power purchased agreement demonstrated in Figure 5.

Fig 5. 20MWp/16 MW AC Solar Power Plant, Maharashtra

The installations of both outdoor and indoor types of inverters are demonstrated in Figure 6(a) and Figure 6(b).

Fig 6. (a). Grid inverter (Outside), (b). Grid Inverter (Inside)

5 Results and Discussions

In this practical work we identified various faults, major, minor, and cautionary faults and their troubleshooting procedures are elucidated in the present study with coding of faults, and its alarm level. Before our studies it was very difficult for the solar inverter engineer to identify the faults and power restoration was possible after 2-3 hours. This types of fault causes a loss around 3000 kWh per MW per day. Now quick fault identification is possible with the help of Sungrow software DSP1_20_VA_J & IDM- AC Fm ver, Demonstrated in Table 5. Hence, we save huge generation loses as well as revenue.

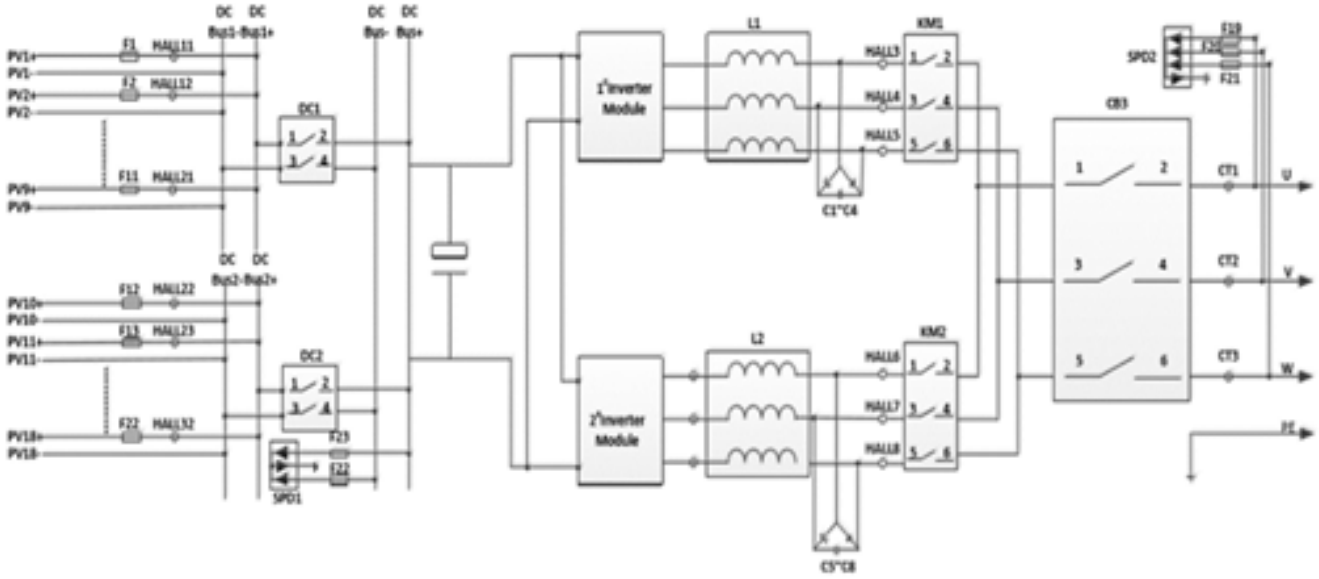

Fig 7. Internal diagram of grid connected solar inverter

Table 5. Summary of different types of faults and alarm in a Grid-tied inverter

Fault Code	Fault explanation	Alarm Level
Driver board	Driver board fault	Major
Center- fault	Contactor faulty	Major
Mism-lac	AC current is unbalanced	Major
L over -temp	Reactor temperature is excessively high	Major
Vdc-low	DC voltage is excessively low	Major
Bus under-voltage	Bus voltage is excessively low	Major
Temp-fault	Temperature is excessively high	Major
Vac-high	Grid voltage is higher than the set	Major
F-fault	Grid frequency is abnormal	Major
Vac-low	Grid voltage is lower than the set	Major
Island-No grid	Grid blackout	Major
Control power sup- fault	Control supply is abnormal	Major
DC-SPD fault	SPD on DC side is faulty	Major
AC-SPD fault	SPD on AC side is faulty	Major
Vdc-high	DC voltage of module is high above set value	Major
AC switch fault	AC switch are faulty	Major
External power supply	External power supply is abnormal	Minor
Branch breaker fault	Circuit breaker on DC branch circuits are abnormal	Minor
CT Unbalanced-fault	3 phase grid current is unbalanced	Minor
Frequency shift Watt adjective	Active power of inverter is adjusted ac to change in grid	Warning
GFRT run	Grid fault occurs, the inverter can ride through the time	Warning
Radiator over temp-fault	Temperature of heat sink is excessively high	Major
AC fuse -fault	AC fuses are abnormal	Major
GFDI pro-fault	DC grounding protection abnormal	Major

6 Conclusion

Solar photovoltaic power plant installation in India has gained momentum and has given national importance after Paris Agreement (COP 21) 2015. The government target is to install 100 GW solar PV plant by 2022. For reliable power generation, inverter has vital role in a solar power plant. The researcher explores on various operative faults such as major, minor and warning types. Generally, voltage imbalance, frequency abnormal with leakage current and insulation failure faults are shown in many on-grid solar power plant. Modern technology need to be adopted for the proper detection of the inverter faults and its troubleshooting. For quick fault detection of the inverter, we use a modernized software DSP1_20_VA_J &IDM- AC Fm version. The software helps to detect fault of the inverter within 0.023 milli-second and send a message to the service engineer for rectification. According to earlier studies it was very difficult for the solar inverter engineer to identify the faults and power restoration was possible after 2-3 hours. This troubleshooting process mitigate the inverter faults to minimize the power plant generation loses. The present research can be of immense help to the service engineers and field workers to minimize various inverter faults, troubleshooting time, save energy of around 3000 kWh/MW per day. This will aid to the future developers and researchers for optimizing the power generation and payback period of the solar power plant.

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