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 un-serviceable. 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](https://www.indjst.org/)

| 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                 |

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.
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 inlet is 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 inlet is 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 in voltage input 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 in voltage input 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 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 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) to Figure 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).

| 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

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| 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

![GFRT fault by the software DSP1_20 VA_J & IDM AC Fm ver](https://www.indjst.org/)

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/m\(^2\) 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.

![20MWp/16 MW AC Solar Power Plant, Maharashtra](https://www.indjst.org/)

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

![Grid inverter (Outside), Grid Inverter (Inside)](https://www.indjst.org/)

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.
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_V A_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.

Acknowledgements

The authors express their appreciation to the Aditya Birla Renewable Energy, Sun grow and Ms. WAAREE Energy, Department of Energy and MAHAGENCO for supporting this work.

References

1) Energy. The World Bank. Available from: https://www.worldbank.org.
2) International Renewable Energy Agency (IRENA). Global Energy Transformation: A roadmap to 2050. 2019. Available from: https://www.irena.org/
3) Sustainable Development Goal 7 (SDG7). Affordable and clean energy. Available from: https://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-7-affordable-and-clean-energy.html.
4) World Economic Outlook(WEO). The gold standard of energy analysis, 2020. Available from: https://www.worldbank.org/en/research/world-energy-outlook.
5) World Bank. Solar Photovoltaic Power Potential by Country, 2020. Available from: https://www.worldbank.org/en/topic/energy/publication/solar-photovoltaic-power-potential-by-country.
6) Muni V, Lalitha S. Technical issues of Grid connected solar photovoltaic cell - A survey. International Journal of Current Research and Analysis. 2017;10:913–920.
7) [7] Energy Sector Management Assistant Program (ESMAP). Global Solar Atlas 2.0, Technical Report. Washington, DC: World Bank, 2019. Washington, DC: World Bank. 2019. Available from: http://documents1.worldbank.org/curated/en/529431592893043403/pdf/Global-Solar-Atlas-2-0-Technical-Report.pdf.
8) [8] Energy Sources. Solar, Department of Energy, 2020. 2020.
9) Renewables. Global Status Report, Renewable Energy Policy Network for the 21st Century (REN21), 2019, 2019. Available from: https://www.ren21.net/gsr-2019/chapters/chapter_01/chapter_01/.
10) The International Energy Agency (IEA). Technology Roadmap, Solar Photovoltaic Energy” (PDF), 2014. 2014. Available from: https://webstore.iea.org/technology-roadmap-solar-photovoltaic-energy-
11) Government of India. Ministry of Power (MoP), 2021. Available from: https://powermin.nic.in/.
12) Annual Report. Ministry of New and Renewable Energy (MNRE), Government of India, 2018-19. 2018. Available from: https://mnre.gov.in/annual-report.
13) Government of India. Physical Progress. Ministry of New and Renewable Energy (MNRE), 2019. Physical Progress. 2019. Available from: https://mnre.gov.in/physical-progress-achievements.
14) National Institute of Solar Energy (NISE), Government of India. Available from: https://nise.res.in/.
15) Haririi MRM. Grid-Connected PV Generation System-Components and Challenges: A Review. Energies. 2020;12:4279. Available from: 10.3390/energies12094279.
16) K PS, D BD, S SBG, K SA. Performance analysis of grid interactive solar photovoltaic plant in India. Energy for Sustainable Development. 2018;47:9–16. Available from: https://dx.doi.org/10.1016/j.esd.2018.08.003.
17) Ellabban O, Abu-Rub H, Blaabjerg F. Renewable energy resources: Current status, future prospects and their enabling technology. Renewable and Sustainable Energy Reviews. 2014;39:748-764. Available from: https://dx.doi.org/10.1016/j.rser.2014.07.113.
18) Gupta CL, Ramachandran A. Solar Energy for India Status, Potential and Impact. Journal of Scientific and Industrial Research. 2003;62(1-2):25–45.
19) Dondariya C, Porwal D, Awasthi A, Shukla AK, Sudhakar K, R MMS, et al. Performance simulation of grid-connected rooftop solar PV system for small households: A case study of Ujjain, India. Energy Reports. 2018;4:546–553. Available from: https://dx.doi.org/10.1016/j.egyr.2018.08.002.
20) Yadav SK, Bajpai U. Performance evaluation of a rooftop solar photovoltaic power plant in Northern India. Energy for Sustainable Development. 2018;43:130–138. Available from: https://dx.doi.org/10.1016/j.esd.2018.01.006.
21) Giri NC, Mishra SP. Energy remediation by alternate dissemination: SPV/PSO power in India. International Journal of Current Research. 2017;9(8):56391–56397.
22) India on track to achieve 175 GW of renewable energy by 2022, Times of India, 2019, 2019. Available from: https://economictimes.indiatimes.com/small-biz/productline/power-generation/india-on-track-to-achieve-175-gw-of-renewable-energy-by-2022-government/articleshow/71614562.cms.
23) India releases state targets for 40GW rooftop solar by 2022. Available from: https://www.pb-magazine-india.com/2019/09/27/the-roadmap-to-40-gw-rooftop-solar/.
24) Bano T, Rao K. Performance analysis of 1 MW grid connected photovoltaic power plant in Jaipur, India. Energy Eff Techno for Sustain (ICEETS). 2016;6:165–170.

https://www.indjst.org/
25) Heynen AP, Lant PA, Smart S, Sridharan S, Greig C. Off-grid opportunities and threats in the wake of India’s electrification push. *Energy, Sustainability and Society*. 2019;9(1):1–10. Available from: https://dx.doi.org/10.1186/s13705-019-0198-z.

26) Giri N. Analysis and Designing of 1 MW SPV Gross Metering Power Plant in Odisha. *International Journal of Emerging Technologies and Innovative Research*. 2019;6(6):608–619.

27) Giri NC, Mishra SP, Mohanty RC. Performance Parameters, Optimization, Recommendation in Large Scale On-Grid SPV Power Plant, Odisha, India. *International Journal of Modern Agriculture*. 2020;9(4):159–167.

28) Padmavathi K, Arul DS. Performance analysis of a 3 MWp grid connected solar photovoltaic power plant in India. *Energy Sustainable Development*. 2015;74(7):411–415.

29) Kalita P, Das S. Feasibility study of installation of MW level grid connected solar photovoltaic power plant for northeastern region of India. *Sādhanā*. 2019;44(207):1–24.

30) Tekpeti BS, Kang X, Kheshti M, Jiao Z. Modeling and fault analysis of solar photovoltaic grid-connected systems under solar radiation fluctuation consideration. *International Transactions on Electrical Energy Systems*. 2018;28(8):e2576. Available from: https://dx.doi.org/10.1002/etep.2576.

31) Narendiran S. Grid tie inverter and MPPT - A review. *IEEE Explore*. 2013. Available from: 10.1109/ICCPCT.2013.6529017.