Photovoltaic Plant Power Flow Monitoring and Data Recording System

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Abstract- A customary power management system deals with the function of overlooking the power flow through a source or system. Solar PV technology based power plants are normally installed in barren areas off from city mainland. It requires a dedicated team to perform continuous monitoring of the setup, incurring additional cost. A remote monitoring system can be implemented to look after the vital parameters of the system and perform self-maintenance which will evade the dependency of maintenance, third-party services. This system discussed in the paper consists of micro-controller based monitoring system which monitors essential parameters of solar inverter continuously, which are provided to a server through GSM module.

Keywords: *Solar PV system, GSM Module, Controller, Power Management*

I. INTRODUCTION

In recent times, Solar PV power plants are being installed all over India to generate clean energy from them. Research activities are in progress to obtain the optimum results from Solar PV. There are many ways in which one can install PV panels i.e. it can be implemented as Large MW on-grid plants with input to the grid, or it can be a small scale Off-Grid setup majorly used in domestic areas, or it can be installed in hybrid mode . In major application areas, solar is effected by discontinuous output so it becomes a compulsion to use it along with inverter-battery system. Solar inverters are developed on large scale and are being commercialized all over the world. Commercially, solar inverters are installed in enormous numbers and in order to ensure that solar inverters provide the optimum results, they must be monitored and built. But it gets very difficult and time overriding task to scrutinize all of them manually. Hence, to reduce the time and complexity required to monitor them remote monitoring systems are implemented. It also makes sure that these systems are monitored without any corporal intervention, and also reduces the chance of their failure to the greater extent. When it comes to maximizing the power and profit, monitoring commercial solar photovoltaic (PV) system is essential. There are rare instances of Solar PV failures, but the operation efficiency may drop down drastically. Without an effective monitoring system, any minor issue can go unnoticed, and thereby impede the energy production and revenue stream that your solar PV system is expected to generate. Photovoltaic monitoring systems can be split into three different categories:

1) *System-level monitoring:* - System-level monitoring provides insight at a PV energy meter level. A PV energy meter is a requirement for state or utility-level incentive based PV system programs. This meter will tell you the total system generation, but any equipment fault on a site isn't communicated.
2) *Inverter-level monitoring:* - Inverters are responsible for transforming Direct Current (DC) from solar panels into Alternative Current (AC), which is compatible with your facility's electrical system. Since inverters are critical in converting energy, monitoring them is crucial. Inverter-level monitoring is a standard method of gathering a PV systems performance and status information. This level of monitoring combines system-level monitoring with an additional set of data points to enhance system visibility.
3) *Module-level monitoring:* - Module-level monitoring provides information on individual panels. It increases the visibility for an entire site, including system-level and inverter-level monitoring. This makes it easier to locate any potential issues, such as broken or shaded modules. The ability to readily identify the source of a problem will cut down the amount of time a technician needs to spend on-site and reduce your maintenance costs.

II. SYSTEM REQUIREMENTS

Monitoring and control of photovoltaic systems is essential for reliable functioning and maximum yield of any solar electric system. The simplest monitoring of an inverter can be performed by reading values on display - display (usually LCD) is part of almost each grid-connected inverter. Most important inverter and grid related parameters are available on LCD screen in such case. Values like PV array power, AC grid power, PV array current are usually available. For sophisticated monitoring and control purposes environmental data - like module temperature, ambient temperature, solar radiation, wind speed can also be data logged, stored and analyzed later. Remote control and monitoring can be performed by various remote connections: analog modem,

ISDN, GSM etc. The most common connection for local/remote control is USB (sometimes even RS232) for local monitoring, RS485 and power line for inverter interconnection. For wireless connection Bluetooth and Wi-Fi can be used. Most simple way to perform local monitoring is display available on inverter or on inverter control unit. Other steps includes monitoring by local controller via RS232 connection and/or remote display located in living room for example (connection between inverter and display is usually wireless). The following parameters can usually be monitored, data logged and stored in inverter's memory or external data logger for particular time (up to 1 year usually). Sometimes additional sensor related units (external or internal) are also required. Major important parameters are ought to be monitored by any PV monitoring system are given in Table I and Table II.

Table I-Common Inverter/Grid Monitoring Parameters

Parameters	Symbol	Unit
Array voltage	V_{DC}	V
Grid voltage	V_{AC}	V
Array current	I_{DC}	A
Grid current	I_{AC}	A
Array power	P_{DC}	W
Grid power	P_{AC}	W

Remote control and communication between inverters can be realized with wireless connection (Bluetooth or Wi-Fi), through RS485 interface or via grid (power line connection). Distances up to 1200 m represents no problem, several tenth inverters can be connected in chain and monitored at the same time. For remote monitoring different ways of communication can be used: Ethernet, Internet, dial up access, GSM etc. System can send alerts and status messages to the control center or user.

Table II- Common Ambient Monitoring Parameters

Parameters	Symbol	Unit
Module temperature	T_{mod}	°C
Ambient temperature	T_{amb}	°C
Global irradiance	G	W/m^2
Global irradiation	H	J/m^2
Wind speed	v	m/s

Data can be stored in inverters memory or in external units (data loggers). Different solutions are available on the market. Some producers offer also additional memory increase or upgrade. Better data loggers offer monitoring functions (data logging) for various environmental and additional system related parameters what can give the user detailed overview about the whole system. Additional parameters that can be monitored are module- and ambient temperature, solar radiation, solar irradiation, wind speed (hybrid systems), in some cases also air pressure and air humidity (sophisticated electronic weather station) etc. Temperature sensors are usually PT100 or PT1000 sensors. Solar radiation is measured with reference solar cells (Si-mono), analog inputs of the control equipment are usually standard 4-20mA or 0-10 V inputs. Digital inputs are also available and can be used for net-meter/control equipment interconnection. Public displays are widely used not only as public monitoring tool they are used as promotional or educational purposes as well. Communication between photovoltaic system and public display is usually realized via RS232 port, some producers offer also wireless connection. Most common display types are LCD displays, numbers can clearly be read from distances up to 40 m, depends on number sizes.

II. METHODOLOGY

Basically the objective of this work is to devise a system to solve the problems faced by Solar PV energy systems which include the accurate and cost effective measurement of the production history of the solar panels and the consumption of the user.

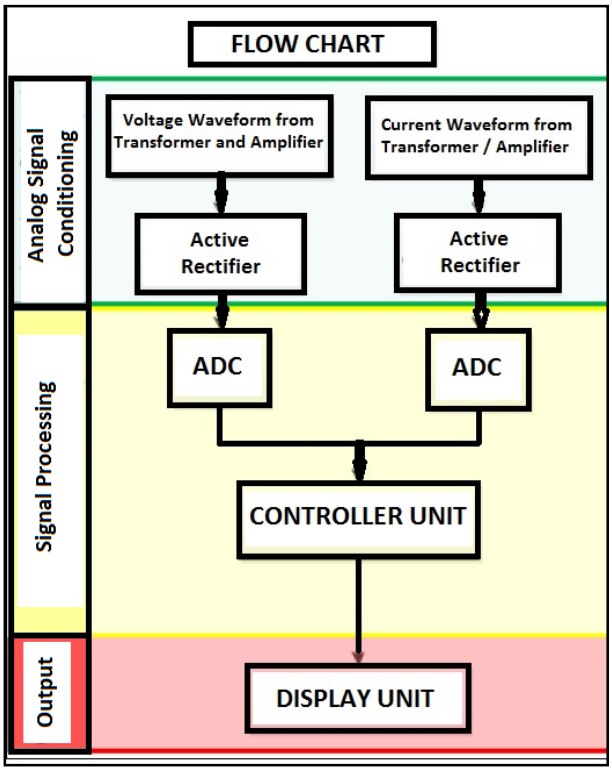

Fig.1. Basic methodology of system

The capabilities of the system for a majorly used Grid connected Solar PV system with Grid interactive features can include:

a) Solar PV generation

b) Site-consumption

c) Solar PV generation used on-site

d) Solar PV generation exported to the grid

e) Electricity imported from the grid

f) Real-time & historic daily, monthly and annual totals

In the type of installation shown in figure 2, the generation and site-consumption can be monitored separately. The amount exported/imported to or from the grid is the difference between generation and site-consumption.

In the type of installation shown in figure 3, when the generation and site-consumption cannot be monitored separately e.g. the PV inverter output is fed into the fuse box and the household loads are connected to other circuits in the same fuse box. If this is the case, the output from the PV inverter and the grid import/export connection will need to be monitored and site-consumption calculated by subtracting.

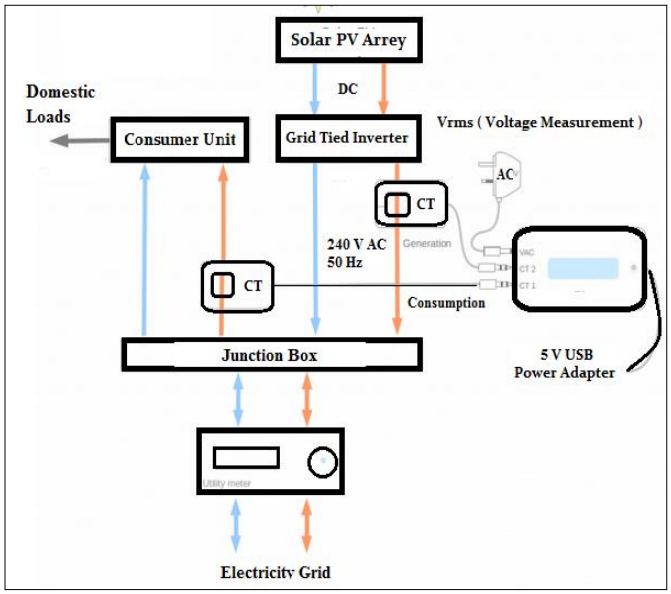

Fig.2. Installation mode for On-site system

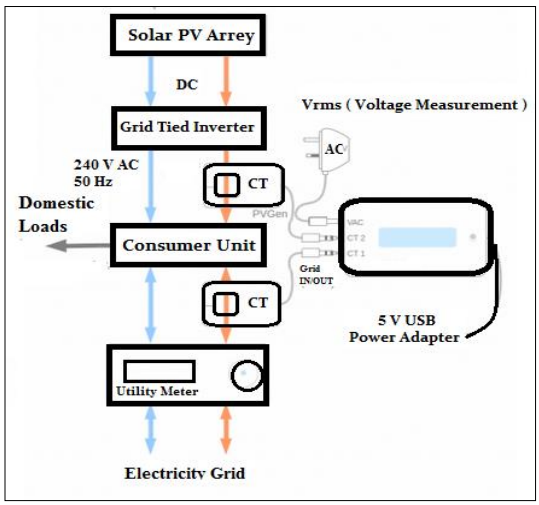

Fig 3- Installation mode for Grid Interactive system

It is important that an AC-AC adapter is used for both type 1 and type 2 solar PV systems. Without an AC-AC adapter the power reading can be significantly wrong - especially at night - due to the low power factor from some solar PV inverters. Further, at times an inverter might be consuming a small amount of grid power; without using an AC-AC adapter there would be no way to distinguish this consumption from generation and establish the true power flow direction.

Clip-on current sensors are non-invasive and should not have direct contact with the AC mains.

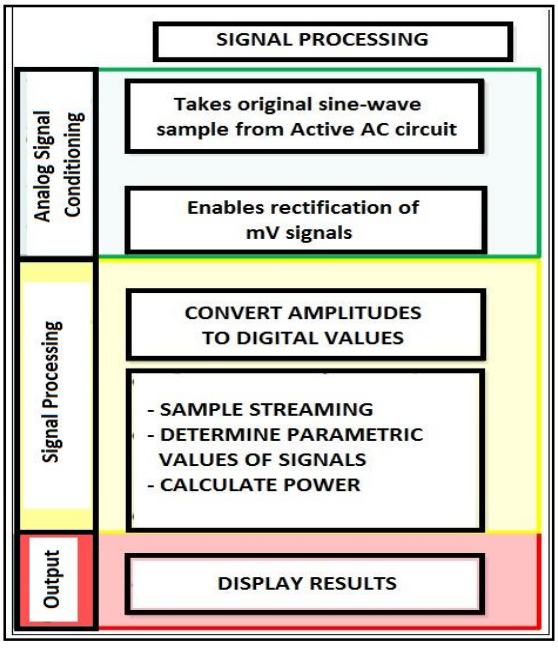

Fig.4. Signal flow in system under study

III. CONCLUSION

The system is developed to collect data from solar PV system installed ON grid or OFF grid through an inverter unit. It monitors the power flow in the system using controller based hardware. It keeps record of power generated, power utilized and power delivered to grid. The system architecture depends on number of parameters enabled to perform recording operation. The result and data are displayed for observation purposes.

IV. REFERENCES

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