IoT based Intelligent Monitoring and Control system for effective utilization of distributed Solar Generation Assets of Agriculture Areas

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Abstract— Gujarat is a leader in the deployment of renewable energy. The state has over 1,500 Nos of grid connected solar PV plants till date and is among the top states in India for solar energy generation. The state has also given emphasis to distributed solar generation i.e. solar generation connected to the LT grid. The Gujarat Energy Development Agency (GEDA) has been implementing the rooftop solar program in lines with the central program of the Ministry of New and Renewable Energy (MNRE). Now, the state intends to extend the definition of distributed solar energy from rooftop solar PV systems to grid connected solar pumps or 'Farm-top' solar installations.

The central government has also planned to make an announcement to support and scale up this pilot project across the country through the Kisan Urja Suraksha evam Utthaan Mahabhiyan (KUSUM) scheme.

The state now envisions to dovetail the efforts through the KUSUM scheme and has announced the Suryashakti Kisan Yojana (SKY) scheme. The scheme is essentially a net-metering solar PV based pump set that is installed on the fields of farmers. The essential working of the scheme is similar to the rooftop net-metering policy in any location in the country. Farmers install solar powered irrigation pumps. The solar PV system provides day-time around 12 hours power to the farmers which is first used to meet the requirements of the pump. Any excess energy is fed into the grid for which the farmers are compensated by the power distribution company.

There are several benefits of SKY scheme, which are, (a) efficient use of water (b) additional source of revenue for the farmer (c) day time power for farmers (d) reduction of cross-subsidy burden on the DisCom (e) deployment of RE in a distributed and equitable manner (d) reduction of long-term power Subsidies for the state government (e) improved economy in rural areas.

Keywords— SKY (Suryashakti Kisan Yojana), Watch Dog Transformer, AG Consumers,Metering Console, SEDM Software-Solar Energy Data Management Software.

I. INTRODUCTION

SKY Scheme is applicable for grid connected existing Agriculture Consumers, farmers would be provided grid-connected solar photovoltaic (PV) systems in their farms adjacent to their pump-set. As per the scheme provision, 1.25 times of the contracted load of the agriculture pump set of the farmer in HP; equivalent SPV system in KW shall be installed. e.g. the existing Farmer with 10 HP contracted load is eligible to install 12.5 KW of SPV system in SKY scheme. Such an arrangement would enable the farmers to inject the surplus generated solar electricity to the grid and will earn extra income from the sale of electricity to DisCom which is supported by Feed in Tariff and EBI- Evacuation Based Incentive. The other major advantages of the scheme are, Farmers will get incentivized to pump water optimally, conserve ground water and help in energizing agricultural feeders and habitations. As being a generation at load point, reducing AT&C losses, DisCom will save huge amount of money by minimizing energy purchase for Agricultural sector also will help to meet their RPO obligations. This would also reduce the subsidy burden on the State Government towards the farmer's electricity, as the State Government would be purchasing power from the farmer rather than selling power to them. But there are challenges to manage power in condition of Solarizes for the Non Solarizes consumes and Energy accounting is required at consumer, Transformer and Feeder input point. To meet these challenges Smart energy management system is developed by using Metering & communication solution and watchdog transformer with IoT technology.

Farmers are benefited from the following viewpoints.

- The ownership of Solar System is of Farmer after Loan repayment.
- Permanent second source of Income to Farmer for injecting surplus energy into the grid and helps to uplift the financial condition of "Annadata" as "Urjadata".
- 12 Hours of power supply during day time with Grid support. This is a huge relief to the farmers as farming becomes much more easy and cheaper.
- It is possible to grow crop under the solar panel as well.
- Consolidation of Rural Economy by Local employment generation opportunity

Use of IoT devices for communication, data acquisition, monitoring and control is increasing at a very rapid rate,

especially in developed countries. India, being a developing economy, is also following the same footsteps. The IoT base communication and monitoring is introduced in the SKY Scheme. For participating farmers, metering scheme by providing all essential energy meters in a single metering console with internal communication arrangement with standardized Modbus protocol and one IoT based gateway device for data acquisition from all meters, inverters, pump etc. and communication with server. Also, the non-participating consumers are being limited to the benefit of the scheme by installing Watch Dog Transformers/Device which is also working on the IoT based monitoring and control system. The Feeder level arrangement of SKY Scheme is as the following Drawing.

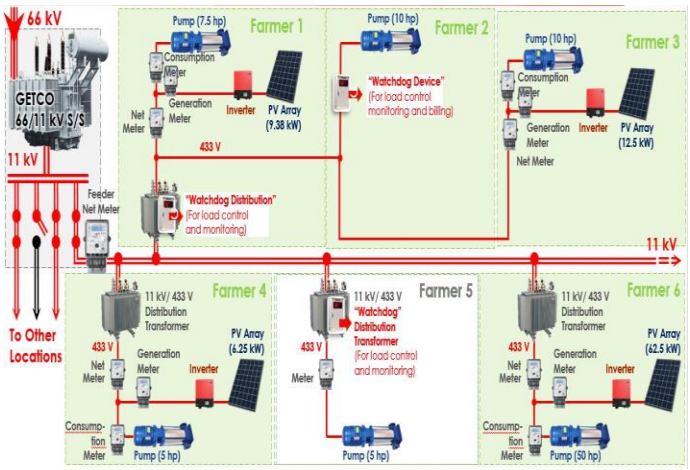


Figure-1 Feeder level *Schematic diagram of SKY Scheme*

Farmers who are the consumers of the DisComs and are connected to the distribution grid shall be the Beneficiaries. They shall be equipped with grid-connected solar photovoltaic (PV) systems in accordance with their existing contract demand. The feeder under the solarization i.e. the Agriculture feeder will be kept 'ON' during the daytime, say from 7 am to 7 pm. The timings may further be adjusted to maximize the solar energy generation. As shown in fig 1, multiple consumers are connected to one feeder. It may, also, happen that some consumers do not opt to participate in the scheme. As the agriculture consumers are highly subsidized in tariff, the three-phase power supply is restricted up to eight hours. For the remaining hours, single-phase supply is catered for their lighting loads through Special Designed Transformer called watch Dog Transformer (WDT).

The Feeder, having solarized system consumers, say SKY consumers are producers and consumers, hence known as prosumers and some, who do not opt to participate, are normal consumers. For monitoring of consumption and injection of energy and for billing purpose, a Smart Energy management system is required. In addition, Feeder level Commercial loss shall be proportionately distributed amongst all the 'Solarized Agriculture Connections' of the feeder. To meet with all above requirements, IoT (Internet of Things) based remote metering and SEDM (Solar Energy Data Management) software-based monitoring scheme developed. As dictated in the above schematic diagram -1, all the nodes of the feeders are covered with live energy measuring system such that energy auditing at each point can be measured.

Major four components are involved in Smart Energy Management. As stated hereunder.

A. Remote metering solution for Prosumers (Metering console)
B. 'Watchdog' transformer for Non-Sky Agriculture Consumers
C. Remote Metering solution for other than agriculture consumers
D. Remote monitoring SEDM (Solar Energy Data Management) software

A. Remote metering solution for Prosumers (Metering console):

A comprehensive metering Console consists of 3 phase 3 nos bi-directional energy meters, and one 1 phase energy meter as per the requirement of domestic load and one IoT gateway DCU, 3 Phase SMPS and other necessary components.

1. Bi-directional Net meter (For billing purpose)
2. Bi-directional Consumption meter (For monitoring the consumption of the Prosumer)
3. Bi-directional Solar meter (For measuring the generation of the SPV system)
4. 1-Ph meter for Farm-house (residential) connection

The indicative drawing of the Prosumer installation is as below.

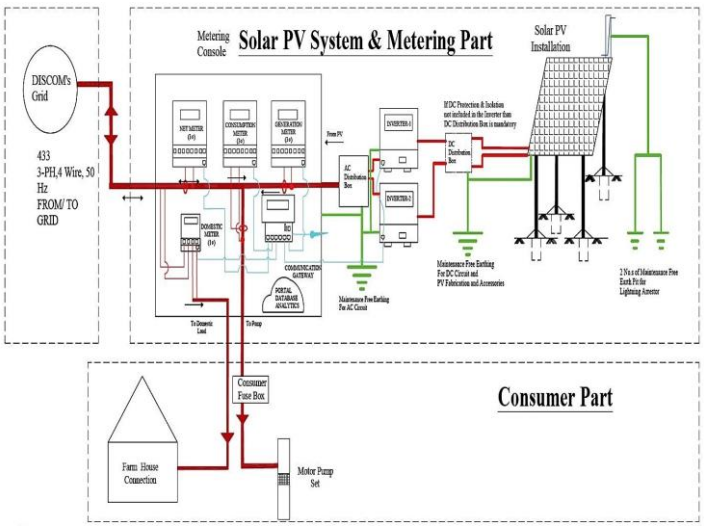


Figure-2: SKY Prosumer installation drawing

All meters are Modbus complied with RS-485 communication port. All these meters can be communicated with the single

IoT gateway as shown in figure-3. The parameters of the inverters are also communicated with the same IoT device.

IoT-based DCU to collect data from all four meters inside the metering console and from inverter at a regular interval of 15 minutes (can be modified in the slab of 1 minute to 1 day, if required in future) using RS 485 port and MODBUS protocol and communicate with cloud server through a secure communication protocol. Also, In the case of other peripheral devices (e.g. Console box door open/ close indicator), the DCU may communicate based on appropriate digital or analog signals.

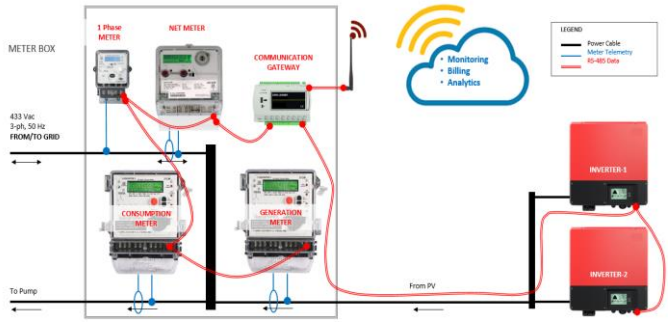


Figure- 3: Schematic diagram of the metering console

In practice, certain maladies are done by AG consumers which can be prevented by this design. By having data of all three meters and live monitoring of the same enable to check energy balance at each node. In case, the energy transaction deviates by more than a certain percentage of error, the Installation checking can be arranged at that particular location. In addition, there is a Future provision in IoT based DCU to control the consumer load by connecting and disconnect command from the remote end through SEDM Software as a Grid Demand Side management.

B. '***Watchdog' transformer for Non-Sky Agriculture Consumers***

Watchdog transformer will be installed at the premises of AG consumers who are not participating in the Scheme. The watchdog transformer is equipped watchdog device to comprise of IoT based programmable smart device which measures all electrical parameters and status of each contactor. To prevent theft by direct hooking, direct access of Low Voltage (LV) terminals are restricted by installing watchdog device on the LV side of the transformer. It will limit the 3-phase power supply to non-participating AG consumers for a stipulated 8 hours, but may continue single-phase power supply for residential purpose for the rest of the hours and also record the energy consumed by the consumer, the energy data and remote connect / disconnect shall be integrated with SEDM.

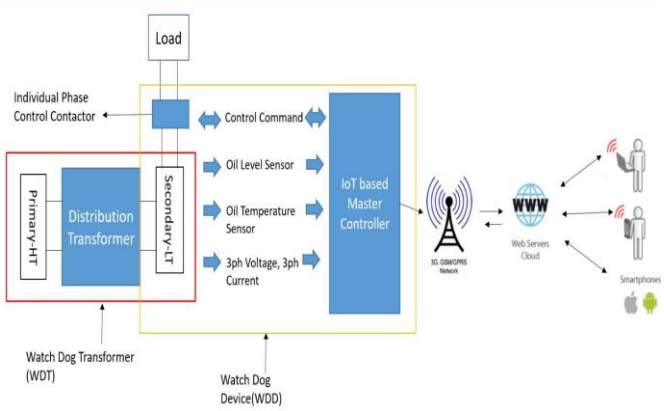


Figure-4: Schematic diagram of WatchDog Transformer.

In addition, watchdog transformer utilized as an Energy audit transformer in the scheme, where nos of agriculture consumers are connected at a single transformer through bare distribution line. In such case, probability of theft is very high as bare conductor type distribution line is accessible any time, watchdog transformer monitor energy audit for every 15 minutes of interval and whenever a difference of energy exceeds than defined limit it will generate the alarm through software.

Furthermore, IoT device can be configured for Overloading, current unbalance and over/under voltage protection which will enhance the life of distribution transformer.

The smart control systems are embedded inside the transformer such that it looks like a conventional transformer. Whatever energy is coming on the bushing of the transformer is pre-measured. This is very helpful in the identification of the theft-prone pockets and makes it convenient for the utility to pinpoint the locations for installation checking drive.

The need for distribution transformer monitoring & Controlling System by WDT

The Distribution Transformer is critical equipment in the power system. The reliable operation of the power system depends upon the effective and successful functioning of the distribution transformer. Almost, the transformers used in the Utilities are having bare/open HT and LT terminals. The consumers are metered, but meters are installed in the premises of the consumers. The notorious consumers indulge with the meter and do not allow to record the energy consumed, properly. In so many cases, the consumers involved, are found strong-headed. Under these circumstances, it becomes very difficult for any utility to control the theft of energy. Therefore the measurement, monitoring, and control of the energy, which comes out of any transformer have to be done with a smart and intelligent device and such a device should be an integral part of the transformer. Any energy comes out of the distribution transformer must be measured before it enters into any consumer's premises.

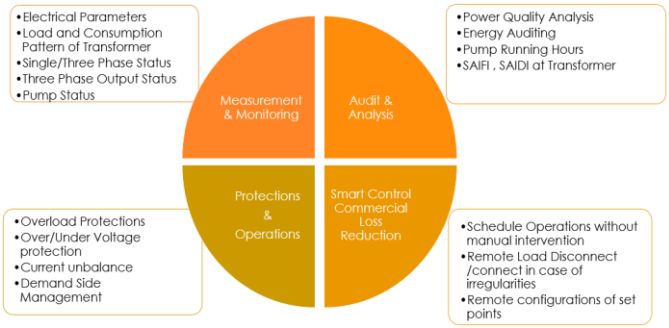


Figure-5 Key features of watchdog Transformer

C. Remote Metering solution for other than agriculture Consumers

All consumers are other than agriculture consumer like. Residential, commercial, etc. of each feeder under SKY scheme are remotely monitored with IoT based DCU and GPRS Communication for day to day calculation of feeder T&D loss.

D. Remote monitoring SEDM (Solar Energy Data Management) software

Solar energy data Management (SEDM) software comprises of various modules like Dashboard for real-time monitoring, auditing and controlling, Billing, asset management, complain management, MIS reports, etc.

DashBoard – Feeder Status covers with following summary for real-time monitoring

- Consumer Summary
- Communication Summary
- Input Status (1ph/3Ph) Summary
- Power Summary
- Voltage Summary (Vmin. /Vmax.)
- Output Status Summary
- Fault status summary

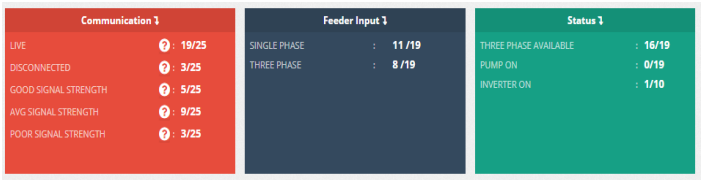
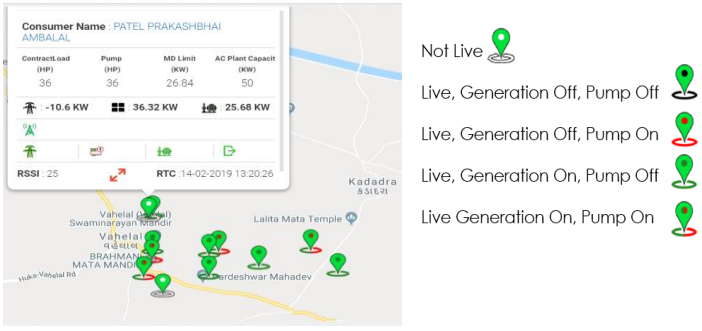


Figure-6

Dashboard – Map View and Grid View summary for real-time monitoring

- Geo Location of Consumer
- Separate Indication based on Current Status
- Consumer Details
- Consumer Type & Ratings
- Communication Status (Date & time)
- Power Status (Generation meter, pump meter, and net meter KW value)
- Output Status (Grid, Pump, and Inverter ON/OFF status)
- Voltage Status (Phase wise Voltage value)
- Hyperlink for Detail Analysis of Individual Consumer



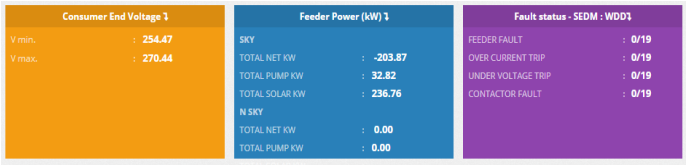


Figure-7: Geo View for real-time monitoring

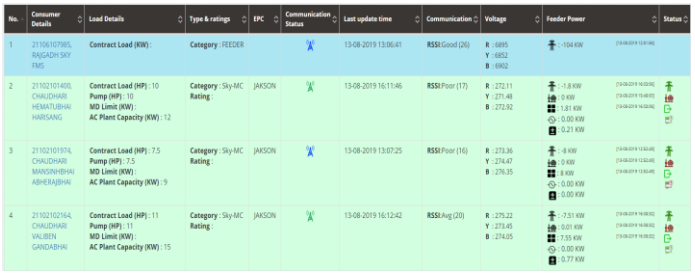
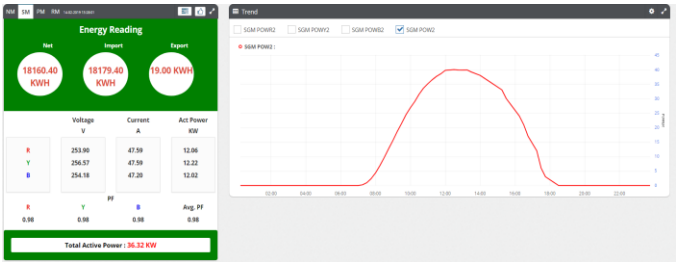


Figure-8: Grid View for real-time monitoring

Grid view facilitates real-time status of IoT device communication, Pump, Inverter, Grid, voltage and Basic Information of consumer.

Dashboard -Consumer wise detail analytics

In this part of the dashboard, we can see Instantaneous data (Voltage, current, power, PF) of each meter and trend analysis of various parameters. In addition, history data of every 15-minute interval available in this module for detail analysis.



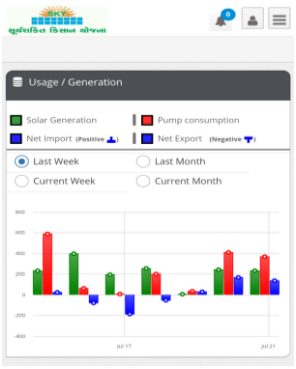
Feeder Level Analysis:

Figure-10: Feeder Level Analysis and Loss Calculation

There is an AMR system for meter readings of a feeder panel meter as well as net meters of each consumer, the system will take energy data of Solar as well as consumption meters, also. DISCOM will perform billing process as per the net energy recorded in the feeder panel meter, after taking technical losses of the feeder into the account. DISCOM shall prepare a common statement of all consumers on a feeder, showing net energy exported/imported. The system shall workout net

amount payable or recoverable from the consumer. As shown in fig.10 software calculate T&D losses of the feeder for a selected duration, CUF of each consumer, Average Generation/day/KW, Feeder downtime and communication downtime as well.

Consumer Mobile Application: Under this scheme, the mobile application is provided to consumers for real-time monitoring status of grid, Inverter, and Pump. In addition, the consumer can also view solar generation, Pump Consumption and Net Energy for a selected duration.



CONCLUSIONS AND OUTCOME

SKY scheme is much beneficial to both the farmers and utility. The scheme envisages huge potential of distributed generation opportunity and at the same time provides the farmer's opportunity to generate the extra income. However, in the absence of any monitoring system, this kind of scheme is quite vulnerable to huge loss to the government. It is therefore much important to effective utilize the latest IoT based communication system which can provide various monitoring facilities. With the same, consumers are also benefited to have the mobile app facility in which they can check their key parameters like SPV generation statistics, Consumption statistics, approx. earnings, etc. These are nowadays the key requirement of success of any scheme. Also, this type of system allows the utility to assess their scheme designing parameters and thereby allow to do the math to come up with the best suited win-win equation for both consumers and utility.

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