American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-7, Issue-8, pp-232-236
www.ajer.org
Research Paper Open Access

Maximizing Solar Energy Yield In Hybrid Grid-Solar-DG Industrial Application

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ABSTRACT:*In industries, Energy mix in different proportion is used. The main energy sources is from utilities and is conventional one (coal, oil, gas). Energy from DG sets, though conventional is used as standby or alternative source. Energy from conventional sources produces greenhouse gases and cause climate change. Considering importance of clean energy solar PV power (Ground mounted or rooftop) can be future alternative main energy source. Optimizing the hybrid Grid-DG-Solar and maximizing clean solar energy in the energy mix is a challenge.*

This research work has developed an energy mix algorithm for maximizing solar energy where it is injected in existing utility grid having standby DG sets energy source. The proportionality of the energy sources in the energy mix in supply side energy management is evaluated and equation established for stabilizing energy demand side energy management in view of maximizing solar clean solar energy in energy mix. Based on algorithm electronic hardware are developed for maximizing solar power of capacity 550 kW power in an energy mix of contracted load of –kW with stand by DG sets of -,- and – respectively. A control unitdeveloped is further tested in real time field operation in industry (latitude, Longitude) having optimum solar energy capacity for a day capacity with net metering system.

The test results shows that the logic developed works accordingly with specific time lag provide in program for 'online' auto operations of supply side energy mix under stabilized load conditions. It is found that the solar PV power is consumed maximum in energy mix all the time when the grid is ON. It is also maximum when grid is OFF and DG throttles to its minimum (30% set by DG provisions)

KEYWORDS–*energy mix, supply energy management, demand side management, hybrid Grid-DG-Solar, maximizing Solar yield, Solar-DG functionality*

Date of Submission: 03-08-2018 Date of acceptance: 18-08-2018

I. INTRODUCTION

A Solar PV system is classified according to functional and operational requirements, component configuration, connected reference power sources and electrical loads. The two main classifications are Grid connected system and OFF-Grid (Stand Alone) system. Photovoltaic systems can be designed to provide DC and/or AC power service, can operate interconnected with or independent of the utility grid, and can be connected with other energy sources and energy storage systems like battery or DG

In large industries, Solar PV system is installed with grid-connected and does not synchronize with DG source due to reverse current and efficiency loss of DG set. Solar PV system cannot generate power in absence of reference power to the inverter. Hence for OFF grid Solar PV system, DG, and solar LT panel synchronization are necessary without reverse current in the system.

II. RESEARCH WORK

A. Grid and DG operations

DG sets are provided as a backup power source in the industry at the time of grid failure. Selection of DG capacity is done on basis of connected load and maximum demand. Two or more small DG sets used in industry instead of one DG which has a capacity equal to maximum demand of company. These two or more

DG sets are operated in parallel with each other by synchronization. Synchronization is the process of running two or more DG sets in parallel on common busbar while matching the characteristics of each system as closely as possible. This is accomplished by minimizing the phase-angle difference, frequency difference, voltage difference &matching phase sequence between the two systems. Also DG sets are throttled to required load demand. By throttling DG sets, fuel consumption is reduced to minimum as possible. A DG sets has limitation as minimum throttling is 30% of its capacity, load below 30% of DG capacity decreases efficiency of DG sets and provision is made to turn OFF DG sets.

B. Demand side energy system

Energy demand management activities attempt to bring the electricity demand and supply closer to a perceived optimum, and help give electricity end users benefits for reducing their demand. In the modern system, the integrated approach to demand-side management is becoming increasingly common.. This allows for very precise tuning of demand to ensure that it matches supply at all times, reduces capital expenditures for the utility. Critical system conditions could be peak times, or in areas with levels of variable renewable energy, during times when demand must be adjusted upward to avoid over-generation or downward to help with ramping needs.

C. Grid- DG-Solar PV hybrid operations

Renewable energy hybrid solutions have significant potential to provide the efficiency and flexibility needed to accelerate the clean energy transition to a renewables-led energy mix. The promise lies in resource complementarities, efficient plant utilization, and ability to closer match production to consumption. The solar PV has imminent potential to improve site production, increase capacity factor, and more fully utilize electrical connection infrastructure and balance of plant equipment. With the utilization of Grid –DG along with Solar PV deployment to system can be shifted in time to more closely match consumption and/or to meet off grid requirements. The hybrid solutions provide flexible energy production and delivery to the local electrical grid. The specific requirements are less attended and a new logic is required to be developed for a stable local grid a least cost and maximizing clean energy. The Fig 1 elaborates an industrial requirement.

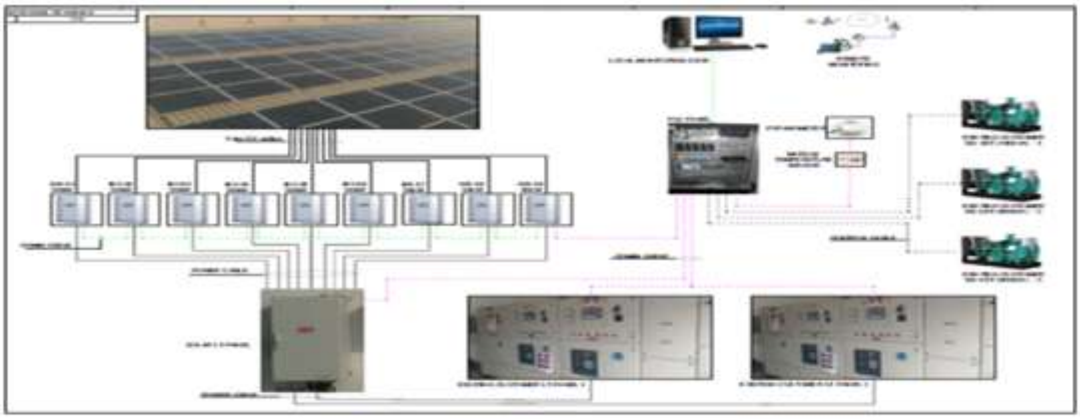


Figure 1 - Industrial requirement of hybrid system

D. Modeling and Logic Development

The hybrid system has Utility Grid, DG set, Solar PV system as an energy mix . Fig 2

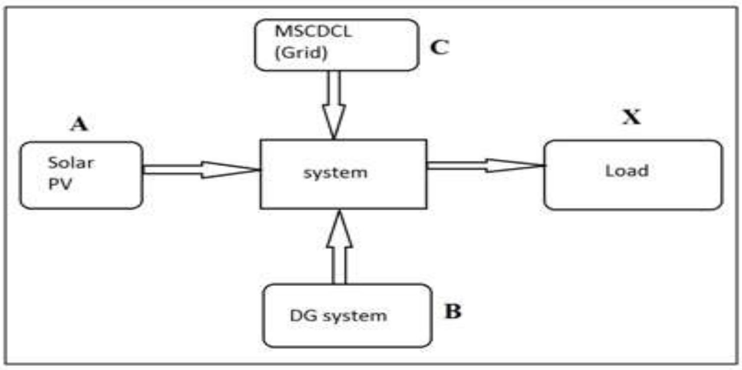


Figure 2 - System Architecture

The general equation for energy demand and supply is obtained by summation of supply-side sources and equate to load i.e kWs.

Load (X) $\leq$ solar PV (A) + DG system (B) + Grid (C) …………………………..(1)

There is an energy mix in X,A,B, & C and can be written a under.

$\sum X = \sum A + \sum B + \sum C$ ……………………………………(2)

Where, $\sum X = X_1 + X_2 + \ldots$

$\sum A = A_1 + A_2 + \ldots$

$\sum B = B_1 + B_2 + \ldots$

$\sum C = C_1 + C_2 + \ldots$

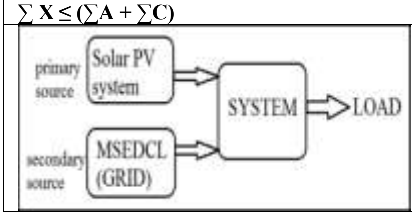
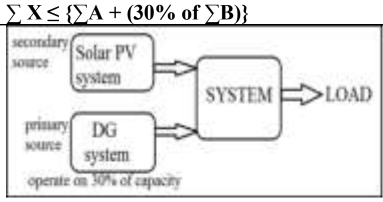
E. Solar yield maximization source A

1. Hypothesis

The hybrid system logic is developed by considering the common condition that summation of total load power is always less than combined power generated from energy mix.The aim is to maximize the solar in puts to it's capacity installed.

$\sum X \leq (\sum A + \sum B + \sum C)$

There are main two cases in logic as,

CASE 1	**CASE 2**
when GRID is present	**when GRID is absent (grid failure)**
$\sum X \leq (\sum A + \sum C)$	**$\sum X \leq \{\sum A + (30\% \text{ of } \sum B)\}$**
	

2. Logic Development

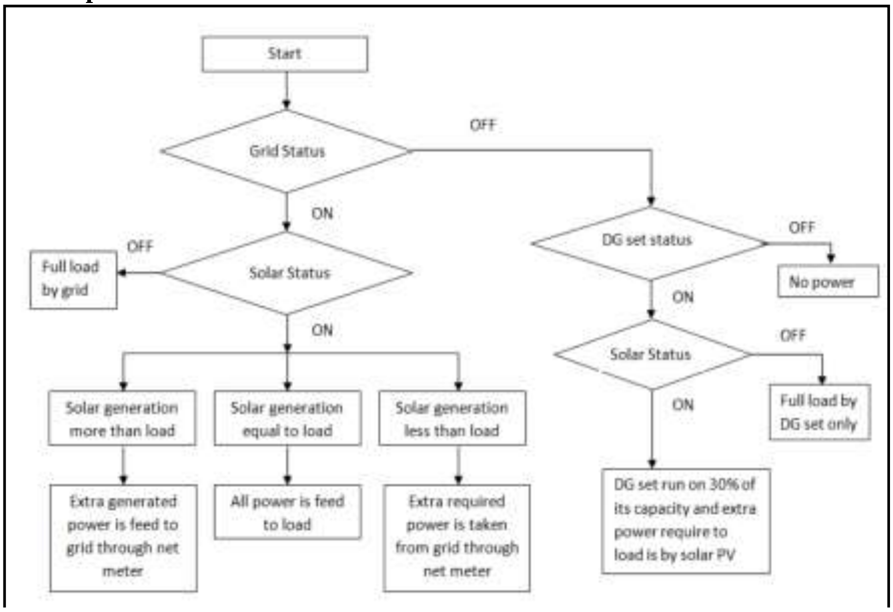


Figure 3 - Flow chart for developed logic

III. TESTING HYPOTHESIS

Logic is tested on the basis of functionality. A procedure is made for testing of system. Observations are taken at SCADA system of the solar PV plant in India. The following energy mix is available

Grid LT:415 V, DG sets 500KVA x2 and 160x1 ,Solar PV 550 kWp, Sanctioned load 1479 kW

Sr. No.	**Load**	**Solar status**	**DG status**	**Point**	**Remar k**
Reduce load from full load					
1	> 240kw	ON	both DG ON	load above 240 kw supply by solar & 240 kw by DG	**OK**
		OFF	both DG ON	All load taken by DG only	**OK**
2	< 240kw	ON	both DG ON	All load taken by DG only	**OK**
		OFF			
3	<240kw	ON	One DG ON,	One DG gets turn OFF	**OK**

	& Stable	OFF	Other OFF		
4	>120kw	ON	One DG ON	load greater than 120 KW supply by solar	**OK**
		OFF	One DG ON	All load taken by DG only	**OK**
5	<120kw	ON OFF	One DG ON	All load taken by DG only	**OK**
Gradually increase load					
6	>370kw	ON OFF	both DG ON (BY CONTROLLER)	DG 2 turned on	**OK**
7	**Any**	**Insufficient output**	**1 or 1,2 DG on**	**All the remaining requirement except Solar power is fulfilled by DG only**	**OK**

The measurements take for type test are good conformity with SCADA observations. This conclude that when the Grid is ON, the solar is injected in system at it's designed maximum capacity. Also when the grid is OFF the operation is successfully executed by logic and device within specified time limits not affect the stability and functionality irrespective of the load conditions. In this case also the solar PV power injected is kept at maximum and DG tries to be minimum as per operating conditions

The Control system is placed in field and tested for real time operation. The example of DG solar operation when grid is off is shown in Fig 4 and Fig 5. (From SCADA)

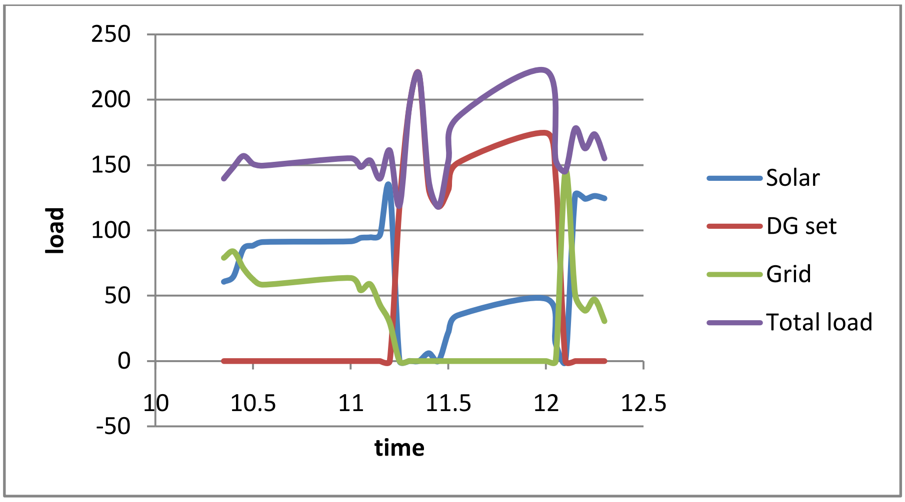


Figure 4 -Load curve for hybrid solar-dg-grid logic by measurements

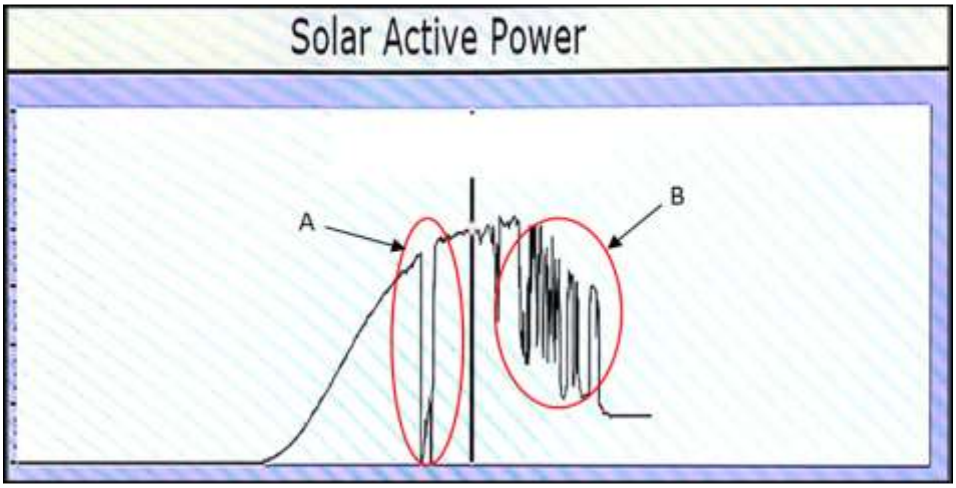


Figure 5 -Load curve for hybrid solar-dg-grid logic by SCADA

IV. CONCLUSION

The research work is carried out to develop a logic for grid-DG-solar functionality and operate it on auto basis at site to maximize solar PV power in the system at least cost without affecting the day to day productivity of the company. The company is having energy sources as 56 HT-I-A Feeder voltage 22 KV, connected/sanction load-1479 KW, Contract Demand -950 kVA back up with DG sets [(2 DG sets of 500 kVA) (1 DG set of 160kVA)] and proposed 550 kWp Solar PV system [on rooftop of industry, under net meter scheme]. The logic, device and operations set through by research work developed are further tested for real time operation. The logics are based on Case 1 – grid is ON, Solar is ON and DG set is OFF i.e. ∑ Load power ≤ power from (∑ Grid + ∑ Solar)AND Case 2 – grid is OFF, DG set is ON and Solar is ON i.e. ∑ Load power ≤ power from {(30% of ∑ DG) + ∑ Solar}.

The operational requirements as per automation on line operation conditions to stabilize the power in system are 30 seconds advance or lag. The logic designed is to start every function with 30 seconds lags i.e. when grid OFF DG starts and stabilizes in 30 seconds, after that solar LT panel stabilizes in 30 seconds, then solar starts within 30 seconds and stabilizes w.r.t. load. A new test procedure is developed for type testing at site to check if new device function accordingly for acceptance test. The system is tested successfully. An economic analysis is further carried out to prove that the developed system operates at least cost. This is done by considering a case in real time operation when the grid is OFF for a day and DG & solar are ON for a day. The capital cost of the system (device) is $ 2250(INR 149000/-_ (Excluding DG automation & SCADA) which is paid back in 12 days when the system operates in real time for a full day.

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