International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-4, February 2020

Modeling and Simulation using MATLAB to Mitigate Technical Challenges & Also for Scalability of Pilot Project of Clustered Solar Agricultural Feeder

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Abstract*: The inclusion of renewable energy in India's electricity mix has been increased dramatically in the past several years. From an environmental, energy security and long-term cost standpoint, this evolving trend is undoubtedly welcome. Solar energy has rapidly emerged as a reliable, affordable and clean solution for meeting India's fast growing energy demand and supply to all. But connecting PV plant DC power with the AC grid is difficult because of tripping, not properly synchronizing. In this paper the development of PV array model, their integration, power quality assessment and Simulink implementation are described. Modeling concept presented in this paper can easily be extended and used for scalability purpose. System consist of solar arrays, MPPT, IGBT inverter and transformer. First, the field parameters has been measured and analyzed by using Fluke Power Analyzer, then exact field modeling and simulation of cluster model of 1.6 MW grid (agricultural feeder)connected PV based solar power plant using MATLAB Simulink R2019A is made in which Maximum Power Point Tracking technique(MPPT) for obtaining maximum possible power output is used, and in MPPT we have used Perturb and Observe method. The ideal values getting from MATLAB Simulation and the real time values of the PV Plant measured by fluke power analyzer are compared and analyzed, then an efficient systems can be modeled for proper synchronization with the grid.

Keywords: MATLAB, MPPT, Fluke, Perturb and Observe

I. INTRODUCTION

In India, it is expected that in 2022, renewable electricity would comprise more than 15 percent of electricity generated in the country. Electricity markets are now expected to take over the role that Government subsidies have played so far.

Revised Manuscript Received on February 28, 2020.
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The sharp reduction in tariffs received in bids for solar and wind power points towards surge in Indian power sector.

Objective of this project under clustered solar agriculture feeder projects in Maharashtra scheme is to provide power to farmers for at least 12 hours a day at cheaper rates and to cater to the agricultural (AG) feeder load of various substations across the state to provide daytime electricity to farmers. Currently each unit of electricity is generated at around Rs 6.50 and the cost will come down to Rs 3-3.25.

The farmers of Maharashtra will get electricity at Rs. 1.20 per unit. Ensure the cheap electricity for the next three years for the farmers of the state.

Above project consists separate Agricultural feeders which feeds electric power to AG pumps consumers and some rural domestic consumers.

The Plan under this scheme is to achieve 1500 MW through this scheme which is to be implemented as Ph-I: 200 MW, Ph-II: 300 MW, Ph-III: 750 MW and Ph-IV: 250 MW. For the integration of renewable energy in the grid, means many new requirements, challenges, issues and risks.

This is because the supply of renewable energy, especially of solar, is intermittent and variable in nature. Grid operators call it infirm or even terrorist power.

In this scenario, matching load and generation, maintaining frequency and voltage, conversion losses and managing reactive power has become significantly more difficult and challenging[1]. The challenges are not restricted to system operators alone.

Transmission utilities need to build significantly more capacity to evacuate power and avoid congestion. Generators need to do a better job of forecasting and optimizing production to avoid penalties and financial losses. Distributors need more active network management to absorb new sources of supply (like rooftop power) and manage demand.

Responding to this evolving trend will require new technical standards, greater transmission capacity, wide area monitoring systems, more spinning reserves, flexible generation, simulation and modeling, proactive demand management, smart meters, energy storage system, net metering, new market and pricing mechanisms, etc.

Fig. 1. 1.6MW PV system of Ralegan Siddhi Area

In this paper, a detailed study of 1.6 MW grid connected PV based solar agriculture feeder project at Ralegan Siddhi, Ahmednagar, Maharashtra(Figure 1 & 2) was done and modeling and simulation of this project is done in Matlab R2019a for ideal output[2]. This paper has been divided into five sections. Section I comprises of Introduction, Section II of PV system description and modeling, section III discusses modeling of the photovoltaic array, Section IV is all about

Fig. 2. Site photo of Grid Connectivity Line

Maximum power point tracking method used, Section V discusses simulation and results, Section VI tells us about conclusion.

II. PV SYSTEM DESCRIPTION AND MODELING

The main and important components of the system are 1.6 MW photovoltaic array, MPPT, Inverter, Transformer and Grid. The photovoltaic array is a combination of series and parallel connected solar panels, the figure 3 describes the basic block diagram of the system which represents how solar energy is transferred and is converted into different forms.

Heat and light Energy from the sun is captured by PV array which converts this energy from the sun into electrical energy which is D.C. in nature so in order to connect this electrical energy with grid this energy is converted to A.C. so for D.C/A.C conversion we use inverter, which converts this D.C. supply into three phase A.C with standard frequency and power factor

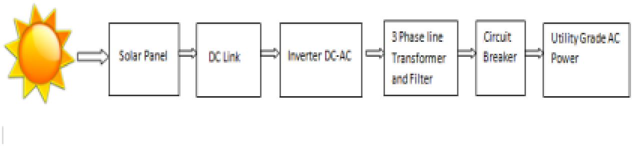

Fig. 3. Block Diagram of PV Grid connected system

after this we use a transformer which increases the voltage upto the requirement of the grid. Thus block diagram gives us an idea of how this whole thing is going to take place i.e. solar grid integration[3].

III. MODELING OF THE PHOTOVOLTAIC ARRAY

The panels used here are WAAREE WS260[4]. These panels are connected in series and parallel to obtain required amount of power. The electrical characteristics of the panel is mentioned in figure 4.

ELECTRICAL CHARACTERISTICS							
Model	WS-240	WS-245	WS-250	WS-255	WS-260	WS-265	WS-270
Nominal Maximum Power, P_m(W)	240	245	250	255	260	265	270
Power tolerance	0/+5 W						
Open Circuit Voltage, V_{oc}(V)	37	37.1	37.2	37.3	37.4	37.5	37.6
Short Circuit Current, I_{sc}(A)	8.65	8.81	8.96	9.12	9.27	9.42	9.58
Voltage at Maximum Power, V_{mp}(V)	30.6	30.7	30.8	30.9	31	31.05	31.1
Current at Maximum Power, I_{mp}(A)	7.85	7.99	8.12	8.26	8.39	8.54	8.69
Maximum System Voltage (V)	1000						
Module Efficiency(%)	14.78	15.09	15.4	15.71	16.01	16.32	16.63
Maximum Series Fuse Rating(A)	15	15	15	15	15	15	15
Limiting Reverse Current(A)	15	15	15	15	15	15	15
*Under Standard Test Conditions(STC) of 1000W/m² irradiance, AM 1.5 spectrum and 25° C Cell Temperature							

Fig. 4. Electrical Characteristics of PV Panel

Power variation can occur due to change in weather conditions or due to load variations. By proper study of temperature and irradiance throughout the year[5], related values are given as input in Matlab2019A as shown in figure 5.

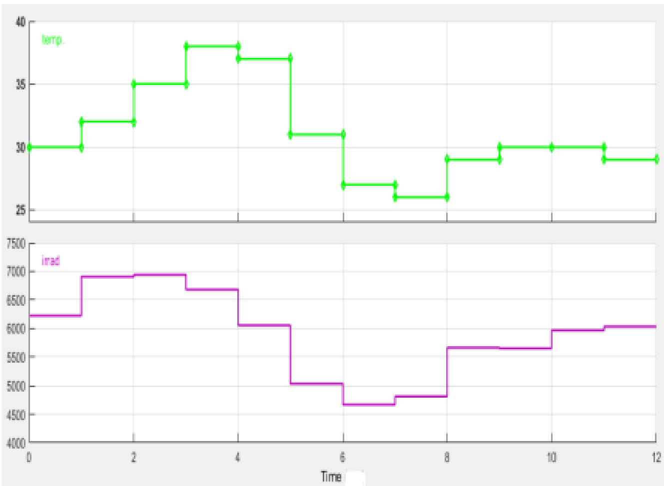

Fig. 5. Temperature and Irradiance

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IV. MAXIMUM POWER POINT TRACKING METHOD (MPPT)

The output power from solar panels is not constant and it is not possible to get maximum power output always as many factors effect power such as solar radiation, ambient temperature and solar cell temperature. so to extract maximum power, MPPT is used. MPPT is an algorithm that includes charge controllers to extract maximum available power from PV modules under all conditions by making them operate at the most efficient voltage i.e maximum power point[3]. This can be achieved by two methods which are Incremental Conductance and Perturb and Observe method[9]. Here, in MPPT Perturb and Observe method is used which is easier to implement in which the voltage is increased by small amount from array and measures power, if the power increases then further adjustment is made in that direction until power stops increasing and algorithm of Perturb and Observe is shown in figure 6.

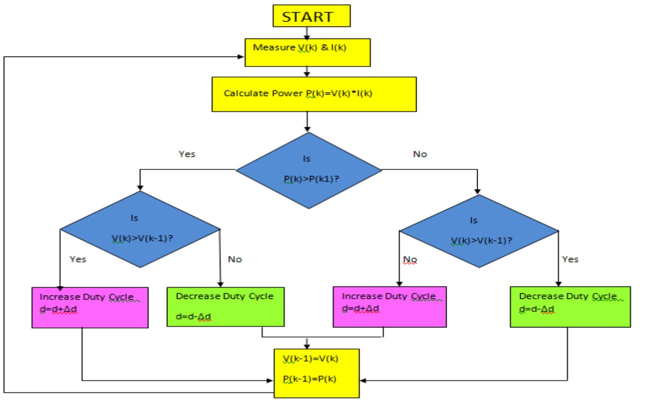

Fig. 6. Flow chart of Perturb and Observe Mechanism of MPPT

V. SIMULATION AND RESULT

The 1.6 MW PV array is connected to a 11 KV grid, The DC voltage generated are boosted and send to Inverter, the inverter convert them around 800 V which is primary to transformer which step-up it to 11 KV which is connected to grid.

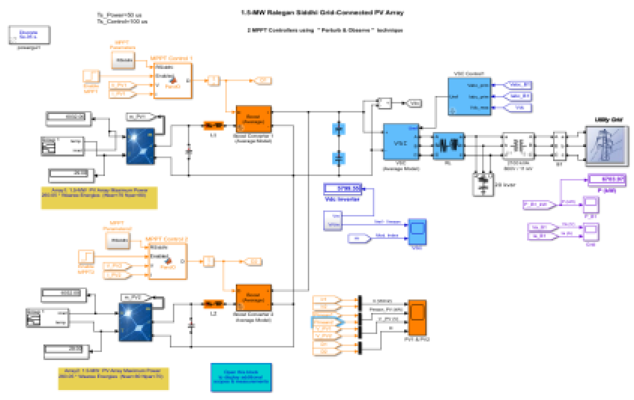

Fig. 7. 1.6MW Ralegan Siddhi PV system in MATLAB Simulink

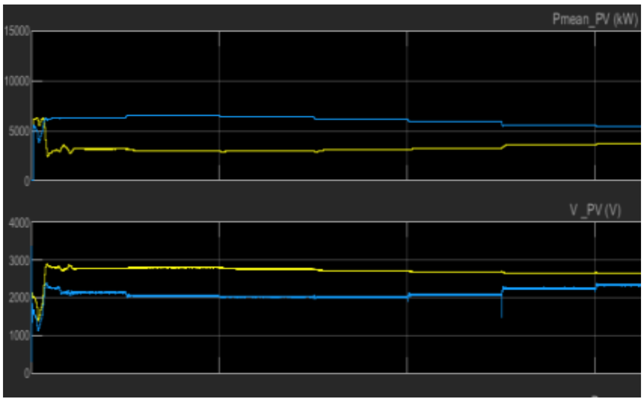

Fig. 8. DC voltage and power values of Simulink

The total Simulink DC output voltage of panels comes between 2000V and 3000V and total DC power fluctuates around 5000KW(figure 8). The grid injecting AC power fluctuates around 5500 KW as shown in figure 9 where as the site inverter output(figure 10) shows lesser values which is quiet low and the system is not upto the mark.

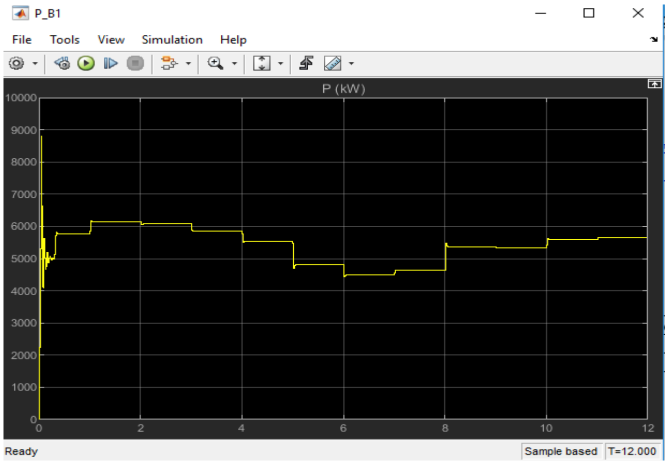

Fig. 9. Grid Injecting Power

Power quality parameters have been measured for half an hour duration sample at solar low irradiance at the output of PV site by using Fluke Power Analyzer[9]. Voltage is fairly sinusoidal but current is not (figure 11 & 12). As per IEEE 519, 2014 voltage harmonics were found within limit. (figure 13).

Fig. 10. Inverter input DC and output AC values

Current harmonics TDD is less than 5% but 5th harmonics is more i.e. 12.407% (figure 14).

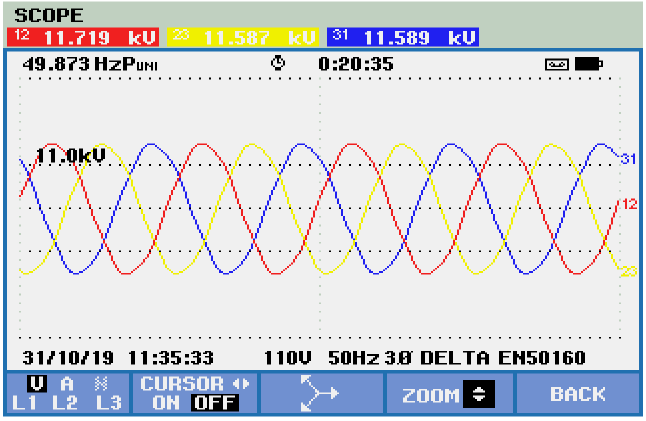

Fig. 11. Output voltage waveform connected to grid

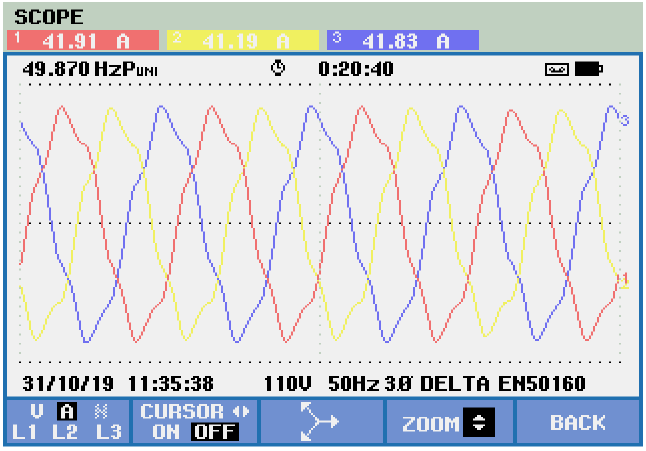

Fig. 12. Output current waveform

The current harmonics here are caused not only by loads of electrical pumps but also due to Inverter/converters of input side. The relation between AC current harmonic multiples and a P-pulse converter is

$h = PN \pm 1$, where N=1, 2, 3…

and P is an integer multiple of 6

for example a six pulse converter can generate 5th and 7th current harmonics and harmonic current is inversely proportional to increasing order of harmonics.Similarly frequency & voltage levels within permissible limit analysis is also done.

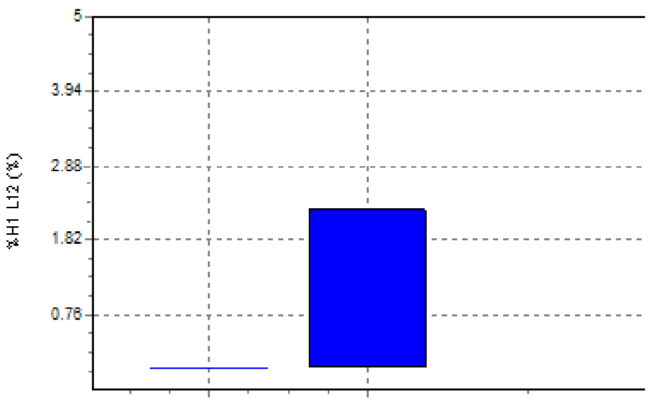

Fig. 13. Voltage Harmonics measured by Fluke Power Analyzer

Although few power quality parameters are within limit but it is recommended to have minimum one day / one week analysis with class A power quality analyzer.

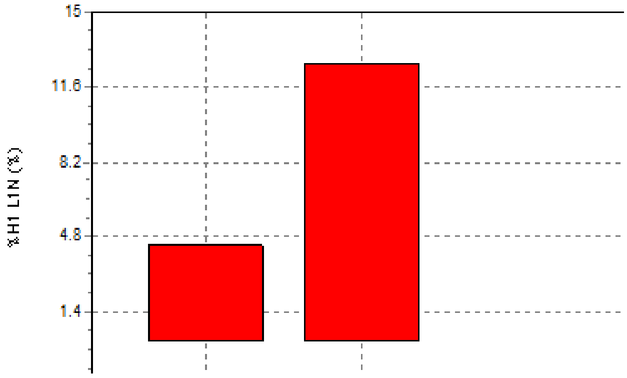

Fig. 14. Current Harmonics measured by Fluke Power Analyzer

VI. CONCLUSION

The site location been in the vicinity of 5 km radius from the 22 / 11 KV substation and substation consists separate Agri-cultural feeders which feeds electric power to AG pumps consumers and some rural domestic consumers. Matching generations with load, maintaining frequency and voltage, im-proper earth values and managing reactive power has become very much difficult and challenging. Discoms need more active network management to absorb new sources of supply and existing (with addition load than sanction load) to manage demand. So from our analysis point of view to mitigate above mentioned challenges connectivity(evacuation) must be at 22 KV or 33 KV level so that reliability of supply with strong protection system to regular persistence/ transient faults can be provided than that at 11 KV level. Also considering geographical and climatic conditions of Ahmednagar, Maharashtra, India, (19.1N 74.8E) tentative total Power Generated from proposed 1500 KWp solar plant will be (Units in 25 years), with allowable degradation: 3,90,00,000. But due to faults/breakdowns, power generated will be around 1,05,66,000. SPV module conversion efficiency should be equal to or greater than 16% under STC which is facing problems due to continuous breakdowns / tripping of feeder. Reasons behind this is adequate loading of feeder is necessary i.e. (feeder loading must not be more than 75% of total capacity). Also heavy initial inrush current due to single phasing feeder requires proper designing of protection and relying system. This results also in inverters used at the low end of their maximum power thus are less efficient. Also high level pulse inverters must be utilized to reduce 5th harmonic. Hence also from MPPT point of view critical analysis of system design for agriculture feeder is necessary for reliable and quality power injection into utility grid, which can be possible by modeling and simulation (Matlab) techniques so that Scalability of pilot project under clustered solar agriculture feeders policies can be implemented affectively.

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