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Projectable Study for PV Grid Connected System

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ABSTRACT

This paper is dedicated to project the effect of connecting PV grid connected system on power quality through a comprehensive simulation, modeling and control of three phase grid connected solar Photo Voltaic (PV) module. The study considers the effect of variation of power gathered from solar system as well as the introduction of penetrating harmonics into the system by the PV inverter. The simulation of the system is performed in MATLAB software using SIMULINK environment and in real time considering an actual case study are presented. An experimental instrumentation is carried out on 40-kW PV array connected to a 12-kV grid via a three-phase three-level Voltage Source Converter (VSC). The technical data was recorded and the power quality of the system was analyzed. The Performance Ratio (PR) of the grid connected PV system is evaluated to determine the reliability and grid connectivity of the PV system.

Key words: PV Grid, Voltage Source Converter, MATLAB, SIMULINK

INTRODUCTION

The conventional method to generate electricity using fossil fuel such as oil, coal and natural gas and these resources have too many drawbacks. Moreover, Last Decade the world was looking for other sources of electricenergy due to Depletion of fossil fuel sources, Pollution and environmentalconcern, the fossil fuel is limited and its prices are getting higher [2]. Although, Solar, wind, Hydro, Geothermal are recommended, wind and Hydro is seasonable, Solar Energy is Permanent, Clean and easy to installremotely where Grid can't be reached.

Recently, the application of solar energy to generate electric power using photovoltaic system [1] increases rapidly in both Stand-alone and grid connected systems. Of theany forms of renewableenergies, solar photovoltaic (PV) technology is one of the most abundant andthere is an increasing demand for PV installations both in grid-connected and instand-alone modes. Solar Energy is a renewable free source of energy that is sustainable andtotally inexhaustible, unlike fossil fuels which are finite. it is also a non-pollutingsource of energy and it does not emit any greenhouse gases when producingelectricity [9].

SYSTEM DESCRIPTION AND MAT-LAB MODELING

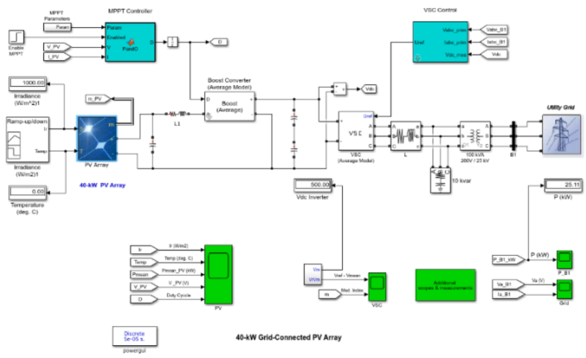

Fig. 1 Mat-Lab File "PV40KW_MPPT

A 40-kW PV array is connected to a 12-kV grid via a three-phase three-level Voltage Source Converter (VSC). Maximum Power Point Tracking (MPPT) is implemented in the boost converter.
The model consists of following components. PV array delivering a maximum of 40 kW at 1000 W/m^2 sun irradiance. DC-DC boost converter 3-level 3-phase 100-kVA 260V/25kV three-phase coupling transformer [1].

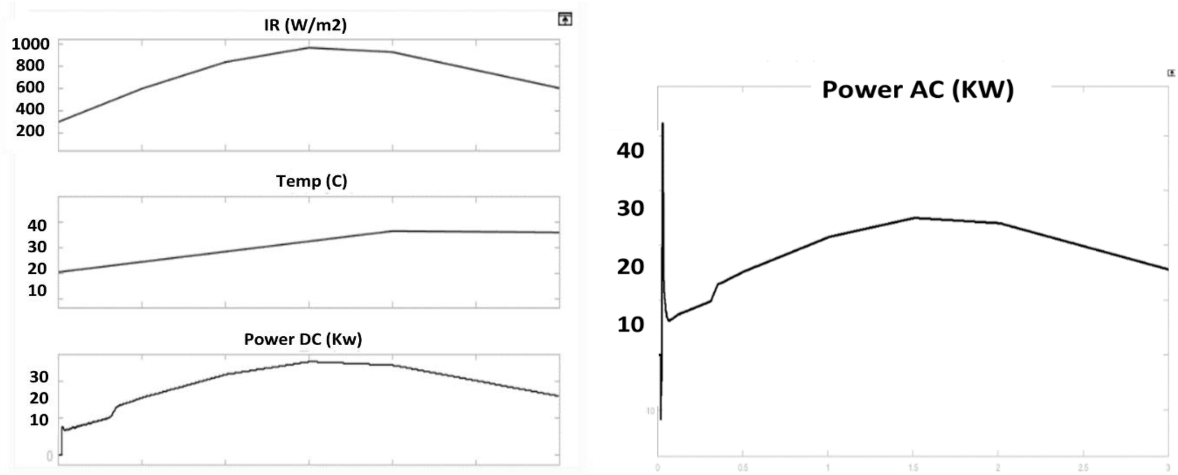

Fig. 2 MPPT DC Power Curves at Daily irradiance and MPPT Delivered AC Power

CASE STUDY

Study of Power Quality at the Point of Common Coupling of a Low Voltage Gridand a Distributed Generation System of 40 kWpat 15th May city, Helwan, Cairo city authority building [4].
The system consists of 140 panels tilted at a fixed angle of 30 and orientedtowards the south with an azimuth of 0º, it is divided into two modules with 70Trina Tall-Max 285 wp polycrystalline which are connected in series covering anarea of 400 m^2. A FroniusSymo 20 kwp inverter with a rated maximumefficiency of 97.9% and maximum AC power of 20 kW is also a part of the circuit,as well as Genius MK6N bidirectional counter which measures the data aboutthe total energy generation.

Tech Data

Solar On Grid Inverter " Fronius Symo 20 kwp "

TECHNICAL DATA FRONIUS SYMO (10.0-3-M, 12.5-3-M, 15.0-3-M, 17.5-3-M, 20.0-3-M)

INPUT DATA	SYMO 10.0-3-M	SYMO 12.5-3-M	SYMO 15.0-3-M	SYMO 17.5-3-M	SYMO 20.0-3-M
Max. input current ($I_{dc\ max\ 1}$ / $I_{dc\ max\ 2}$)	27.0 A / 16.5 A[1]		33.0 A / 27.0 A		
Max. usable input current total ($I_{dc\ max\ 1}$ + $I_{dc\ max\ 2}$)	43.5 A		51.0 A		
Max. array short circuit current (MPP_1/MPP_2)	40.5 A / 24.8 A		49.5 A / 40.5 A		
Min. input voltage ($U_{dc\ min}$)	200 V				
Feed-in start voltage ($U_{dc\ start}$)	200 V				
Nominal input voltage ($U_{dc,r}$)	600 V				
Max. input voltage ($U_{dc\ max}$)	1,000 V				
MPP voltage range ($U_{mpp\ min}$ – $U_{mpp\ max}$)	270 - 800 V	320 - 800 V		370 - 800 V	420 - 800 V
Number MPP trackers	2				
Number of DC connections	3+3				
Max. PV generator output ($P_{dc\ max}$)	15.0 kW_{peak}	18.8 kW_{peak}	22.5 kW_{peak}	26.3 kW_{peak}	30.0 kW_{peak}

OUTPUT DATA	SYMO 10.0-3-M	SYMO 12.5-3-M	SYMO 15.0-3-M	SYMO 17.5-3-M	SYMO 20.0-3-M
AC nominal output ($P_{ac,r}$)	10,000 W	12,500 W	15,000 W	17,500 W	20,000 W
Max. output power	10,000 VA	12,500 VA	15,000 VA	17,500 VA	20,000 VA
AC output current ($I_{ac\ nom}$)	14.4 A	18.0 A	21.7 A	25.3 A	28.9 A
Grid connection (voltage range)	3-NPE 400 V / 230 V or 3-NPE 380 V / 220 V (+20 % / -30 %)				
Frequency (Frequency range)	50 Hz / 60 Hz (45 - 65 Hz)				
Total harmonic distortion	1.8 %	2.0 %	1.5 %	1.5 %	1.3 %
Power factor (cos $\varphi_{ac,r}$)	0 - 1 ind. / cap.				

PV Solar Panels " Trina Tall-Max 285 wp " Trinasolar

ELECTRICAL DATA (STC)

Peak Power Watts-PMAX (Wp)*	285	290	295	300
Power Output Tolerance-PMAX (W)	0 ~ +5			
Maximum Power Voltage-VMPP (V)	31.5	31.8	32.1	32.3
Maximum Power Current-IMPP (A)	9.05	9.12	9.19	9.29
Open Circuit Voltage-VOC (V)	38.8	39.2	39.5	39.8
Short Circuit Current-ISC (A)	9.53	9.60	9.67	9.77
Module Efficiency η m (%)	16.7	17.0	17.3	17.6

Net Way Meter

It's a device which allows consumers who generate some or all of their ownelectricity to use that electricity anytime, instead of when it is generated. Thisis particularly important with renewable energy sources like wind and solar,which are non-dispatchable (when not coupled to storage) [6].

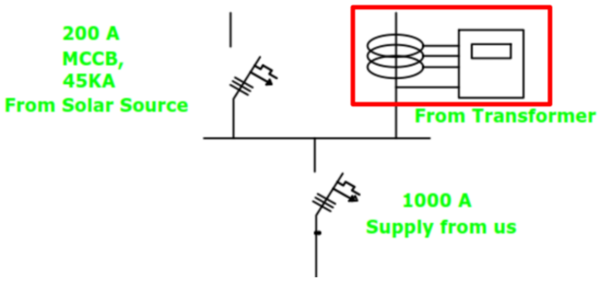

Fig. 3 Net Meter's Point of Connection

Monthly net metering lets consumers use solar power generated during theday at night, or wind from a windy day later in the month. Annual netmetering rolls over a net (kWh) credit to the following month, allowing solar power that was generated in July to be used in December, or wind powerthat was generated in March to be used in August.

ACTUAL READINGS AND DISCUSSION

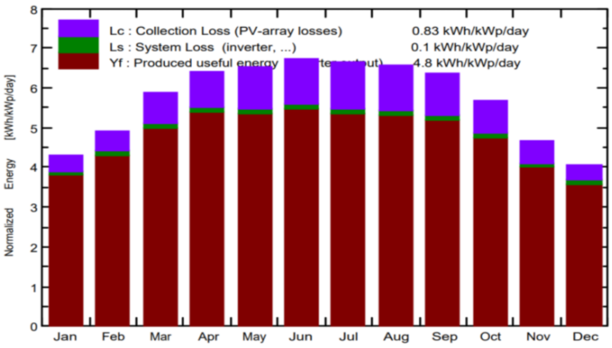

Fig. 4 PV Syst Report

Performance Ratio of Grid Connected System

The lowest values of the monthly reference mean with the rainy seasonand are 40.27 Wh/kWp/day, and 42.18 kWh/kWp/day, respectively,during the months of Dec 2018 and Jan 2019. The highest reference performance values were recorded in May 2019, with 81Wh/kWp/day and 76.67 kWh/kWp/day for the July 2019, respectively. The lowest value of the monthly Energy is 4,193 MWh, because of the lowpercentage of irradiance on this time of the year The highest value of the monthly Energy 6,256 wh, as it is the clearest skyof the year on this month

15th May City Authority
Balances and main results

	GlobHor kWh/m²	DiffHor kWh/m²	T_Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray MWh	E_Grid MWh	PR
January	94.1	42.18	14.33	133.2	129.7	4.536	4.433	0.885
February	108.1	49.45	15.35	137.9	134.4	4.646	4.543	0.876
March	157.7	62.14	18.46	181.8	177.1	5.960	5.832	0.853
April	187.5	76.38	21.40	192.5	186.8	6.217	6.084	0.840
May	216.3	81.39	25.31	202.1	195.6	6.401	6.266	0.824
June	225.8	75.40	27.75	201.8	195.0	6.317	6.185	0.815
July	225.3	76.67	29.37	205.8	199.1	6.398	6.265	0.809
August	206.0	75.63	29.16	204.1	197.8	6.348	6.218	0.810
September	173.7	60.06	27.16	191.5	186.4	5.999	5.875	0.815
October	140.0	53.70	24.24	176.3	172.0	5.661	5.542	0.836
November	101.0	41.46	19.55	139.7	136.3	4.620	4.519	0.860
December	86.9	40.27	16.03	126.3	123.0	4.290	4.193	0.883
Year	1922.5	734.72	22.38	2092.8	2033.2	67.392	65.956	0.838

- **Harmonics**: The sinusoidal component of a periodic wave or quantity having a frequency that is an integral multiple of the Fundamental frequency
- **THD**: The THD is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental component. It provides an indication of the degree to which a voltage or current signal is distorted

- **Effect of Harmonics**

Low Power Factor, Destructions of Functions of Computers , Motor Drives light circuit and static sensitive loads . Transmission Losses in additions Increasing neutral current due to deformation of three phases balance [12].

- **Voltage Total Harmonics Distortion (THDV)**

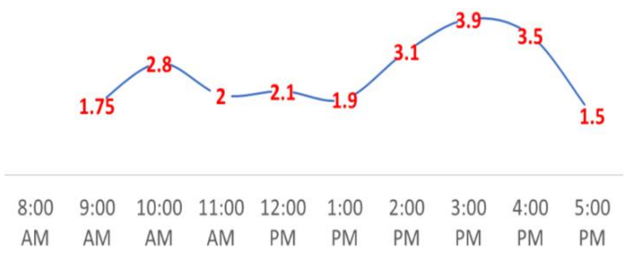

Fig. 5 (THD-V)

The maximum voltage harmonics is of 3.9 % produced by 3rd order, when thesolar PV was injected to the system, and 1.5% when there was no solar PVinjection to the system.

- **Total Harmonics Distortion (Currunt)**

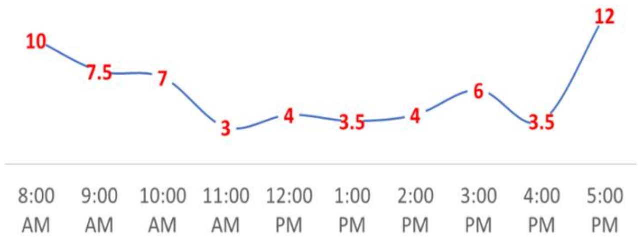

Fig. 6 (THD-I) Before Improvement

Current harmonics was measured from 3rd harmonic up to 7th harmonic byusing Power analyzer. The maximum current harmonics is of 7.5 % produced by3rd order, when the solar PV was injected to the system, and 12% when therewas no solar PV injection to the system.For the system, it is seen that there is a high increase in current harmonicswhen the solar PV is injected to the grid with no load at 8 am and 5 pm.

- **Harmonics Reduction Techniques**

1. Line Reactors	2. Active Filter
3. Hybrid Filter	4. Positive Filter
5. K-Factor and Isolation transformers	

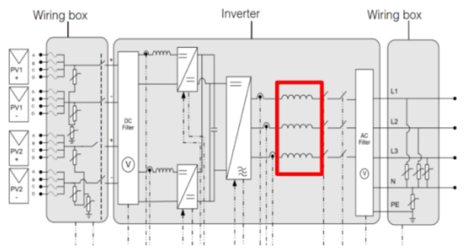

Fig. 7 Wiring Diagram for Added Line Reactor

After Adding Line Reactor to the new model , We will observe that THD for current Hysteresis is now within permissible Limits.

- **Current Total Harmonics Distortion (THDI)**

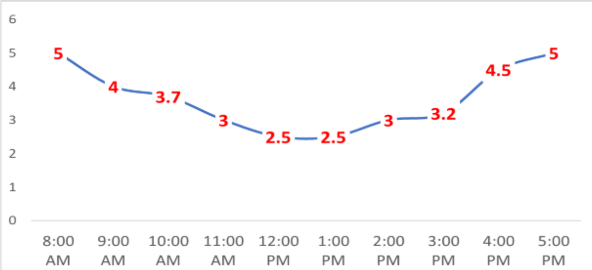

Fig. 8 (THD-I) After Improvement

As shown in Fig. 8, Consequently there is No high increase in current harmonics whenthe solar PV is injected to the grid with no load at 8 am and 5 pm.

CONCLUSION

This study has been carried out to increase the power quality of PV Grid Connected system. Increasing PV demands increases the harmonics to the grid and causes low power factor, destructions of functions of computers, motor drives light circuit and static sensitive loads and increasing neutral current due to deformation of three phases balance. The experimental instrumentation had been conducted on 40-kW PV array connected to a 12-kV grid via a three-phase three-level Voltage Source Converter (VSC). The recorded technical data and the power quality of the system have been analyzed. The power quality parameters such as voltage, current and the total harmonic distortion of both voltage and current (THDv and THDi) were also investigated. From the gathered data, the system was found to be performing as expected and power quality parameters are within the permissible limits. The Performance Ratio (PR) of the grid connected PV system was also evaluated to determine the reliability and grid connectivity of the PV system.

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