IMPACT OF INSTALLATING PHOTOVOLTAIC CELLS ON ELECTROMAGNETIC FIELDS AND ELECTRICAL PARAMETERS

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ABSTRACT

Energy is one of the major inputs for the economic development of any country. In case of the developing countries, the energy sector assumes critical importance in view of the ever-increasing energy needs, requiring huge investments to meet them.
Nowadays, progressive growth in renewable energy sources such as (wind, solar energy) orient distribution companies to update its code in order to achieve maximum power available and guarantee electrical reliability and quality.
The powerful governmental support for Renewable Energy (RE) under the net metering and feed-in tariff scheme in Egypt has witnessed the exponential rise of PV system installation.
Egypt adds many techniques to facilitate introducing new renewable energy technologies, such as, a new program to disseminate PV models into the grid over the buildings which targets about 1000 building in its first phase.
Photovoltaic systems (PV) are the most promising renewable energy sources in Egypt because of its location being in the solar belt where the solar radiation is available around all the year.
Electromagnetic fields are produced by a variety of natural sources and can also be generated by the production and the distribution of electricity.
A large number of the grid-connected PV generators which are connected to distribution networks through PV inverters potentially affect electrical parameters such as voltage, current and THD.

INTRODUCTION

This paper investigates the electric and magnetic fields emission from small-scale PV's 20 kWp in North Delta Electricity Distribution Company (NDEDC) resulting from the operating process and will be analyzed according to the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines.
Also, this paper investigates the electrical parameters' results which were analyzed and evaluated according to the standard IEEE specifications.
The work processes measurement of the areas of electric and magnetic fields on a PV station during its peak.
Generally accepted guidelines have been established for safe public and occupational exposure to power-frequency EMFs. The reference levels for public exposure to 50/60-Hz electric and magnetic fields, according to the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines update are as follows:

- For electric field strength, E < 5 kV/m
- For the magnetic flux density, B <200µ T

These levels for occupational exposure are:

- For electric field strength, E < 10 kV/m
- For the magnetic flux density, B <1000µ T.

The ICNIRP raised the magnetic field exposure level for public guideline which conflicts with findings from some epidemiological research showing an apparent correlation between an approximate doubling in the very low risk of children getting leukaemia and long-term exposure to average fields greater than 0.4 µT.

SITE DESCRIPTION

NDEDC is one of nine electricity distribution companies in Egypt and it has a lot of buildings, the headquarter contains the PV installed on the roof as shown in Fig.1

Fig.1 Photovoltaic Rooftop installed by NDEDC

MAGNETIC, ELECTRIC FIELDS AND ELECTRICAL PARAMETERS MEASUREMENT METHODOLOGY

The magnetic field measurements were performed on a straight line at a height of one meter above the floor of the rooftop between PV panels and around the inverter inside its room. The spot measurements for the electric field were carried out at several points on the roof at a height of one meter above the floor as well.
The spot measurements were recorded by using a 3DH device/E Field Meter over frequencies allowed measurement (5 Hz to 400 KHz), The ESM-100 3D H/E Field Meter is a unique, patented, hand held measuring

instrument which allows easy measuring of alternating electric and magnetic fields at the same time, independent of direction and corresponding to one common point. Fig.2 shows the measurement device.

Furthermore, these measurements were carried out at different solar insolation levels, which affect the output of PV units.

The measurements for electrical parameters have been taken before and after installing PV for 4 days at least by using power analyzer instrument (PQ-Box) fault recorder and network analyzer class A mobile power-quality-network analyzer and power-meter for low-, medium- and high voltage which is shown in Fig3.

Before installing PV, the ground resistance has been measured and found within range.

Fig.4 shows the layout of the installed PV on the roof of NDEDC headquarter.

Fig.2 Measurement Device for Electrical and Magnetic Field

Fig.3 Measurement Device for Electrical parameters

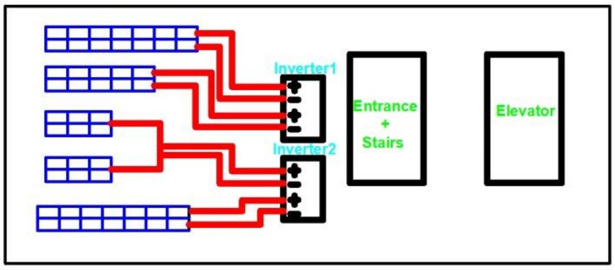

Fig.4 PV Layout

CASE STUDY FOR EMF

The EMF measurements were performed in PV systems mounted on 18th July 2016, between 10 am and 12:30 pm, under clear sky conditions and with an ambient temperature around 38°C. The generated power varied from 15.6 kW to17.66 kW during this period. Magnetic field measured values around the inverter and at distance of (0.5m, 1m and 2m) were in the range of 898 nT-2214 nT and electrical field at the same distance was in the range of 0.81 V/m - 27 V/m which shown in Table1.

Table1: The maximum and minimum electric and magnetic field measured at distance (0.5,1,2m)

Position	0.5m		1 m		2 m	
	Max	Min	Max	Min	Max	min
EF (V/m)	27	1.19	15	0.84	26	0.81
MF (nT)	2214	22	898	21.29	1327	25.17

ELECTRICAL PARAMETER MEASUREMENT

The measurements which have been taken before installing PV are shown in Tables 2 to 6.

The measurements which were taken before installing PV are detected in Figures 5 to 9.

Table2: The phase to neutral voltage at maximum load before installing PV

Date	*Time*	*Phase to neutral voltage*		
		R	*S*	*T*
19/5/2016	10:28	221.2	220.7	220.6
20/5/2016	10:42	218.8	218.1	218.8
21/5/2016	9:34	224.6	223.9	224.1
22/5/2016	10:18	222.6	221.8	221.2

Table3: The maximum load in Amperes before installing PV

Date	*Time*	*Maximum Load in Amperes*			
		R	*S*	*T*	*N*
19/5/2016	10:28	51	133	94	25
20/5/2016	10:42	33	170	93	26
21/5/2016	9:34	42	160	74	23
22/5/2016	10:18	63	152	88	27

Table4: Voltage THD at maximum load before installing PV

Date	*Time*	*Voltage THD at Maximum Load %*		
		R	*S*	*T*
19/5/2016	10:28	2.27	2.8	2.27
20/5/2016	10:42	2.21	2.02	2.17
21/5/2016	9:34	2.16	2.04	2.3
22/5/2016	10:18	1.7	1.6	1.7

Table5: The PF at maximum load before installing PV

Date	*Time*	*PF*
19/5/2016	13:22	0.95
20/5/2016	13:16	0.94
21/5/2016	10:52	0.95
22/5/2016	10:6	0.92

Table6: The Current TDD at maximum load before installing PV

Date	*Time*	*Current TDD %*			
		R	***S***	***T***	***N***
19/5/2016	13:22	9.7	9.42	7.47	30.35
20/5/2016	13:16	8.74	9.98	7.9	17.27
21/5/2016	10:52	9.01	10.45	7.99	25.03
22/5/2016	10:6	6.93	11.38	5.62	17.48

Notes

- ✓ Table3 shows that there is percentage unbalance current exceeding 10% due to unbalance current in three phases, which is within permissible limits at the maximum load before installing PV so it causes an increase in TDD for neutral current as shown in Table 6.
- ✓ After these measurements, the loads were redistributed to achieve balance as shown in Table 8.

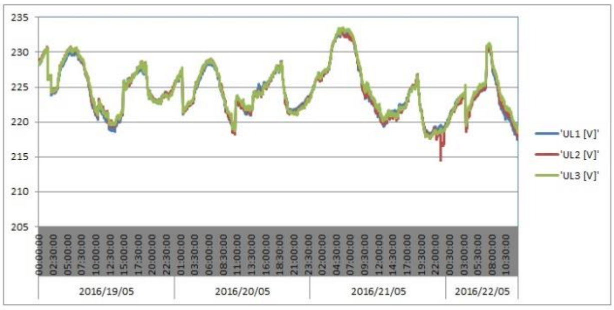

Fig.5 Voltage Variations of building before PV

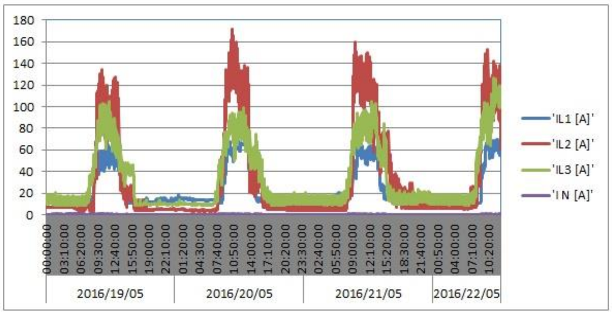

Fig.6 Current Variations of building before PV

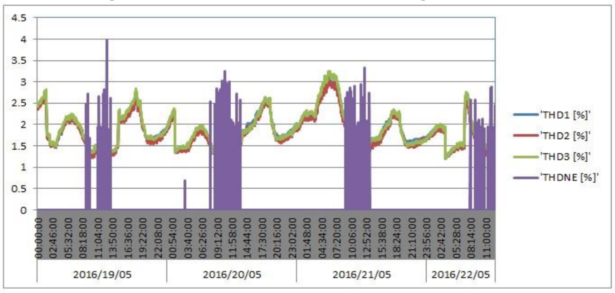

Fig.7 Voltage THD Variations of building before PV

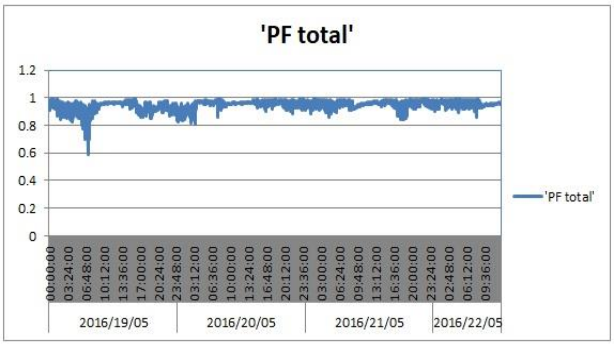

Fig.8 PF Variations of building before PV

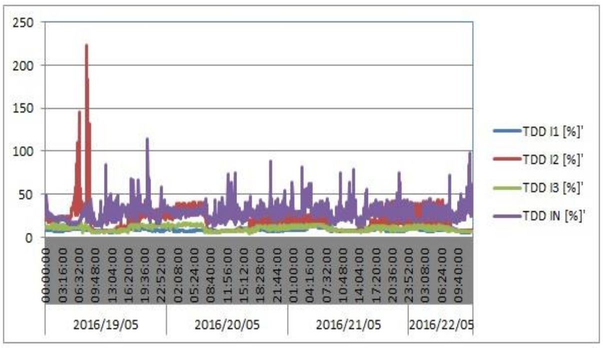

Fig.9 Current TDD Variations of building before PV

MEASUREMENTS AFTER INSTALLING PV

The measurements which were taken after installing PV are shown in Tables 7 to 11.

The measurements which have been taken after installing PV are detected from Fig.10 to Fig.13

Table7: The phase to neutral voltage at maximum load after installing PV

Date	*Time*	*Phase to neutral voltage*		
		R	***S***	***T***
23/5/2016	13:22	225.0	224.2	224.7
24/5/2016	13:16	225.0	224.3	224.7
25/5/2016	10:52	224.1	223.9	224.1
26/5/2016	10:6	224.6	224.8	224.7

Table8: The maximum load in Amperes after installing PV

Date	*Time*	*Maximum Load in Amperes*			
		R	***S***	***T***	***N***
23/5/2016	13:22	83	88	81	6
24/5/2016	13:16	92	86	91	8
25/5/2016	10:52	83	79	81	7
26/5/2016	10:6	97	99	101	3

Table9: The Voltage THD at maximum load after installing PV

Date	Time	Voltage THD at Maximum Load %		
		R	S	T
23/5/2016	13:22	2.27	2.08	2.28
24/5/2016	13:16	2.18	2.03	2.18
25/5/2016	10:52	2.13	2.05	2.16
26/5/2016	10:6	1.76	1.66	1.72

Table10: The PF at maximum load after installing PV

Date	Time	PF
23/5/2016	10:28	0.95
24/5/2016	10:42	0.96
25/5/2016	9:34	0.93
26/5/2016	10:18	0.95

Table11: The Current TDD at maximum load after installing PV

Date	Time	Current TDD %			
		R	S	T	N
23/5/2016	10:28	6.8	6.7	5.9	8.6
24/5/2016	10:42	6.9	6.6	6.1	7.6
25/5/2016	9:34	7.9	7.5	8.3	9.3
26/5/2016	10:18	5.7	7.1	7.2	9.2

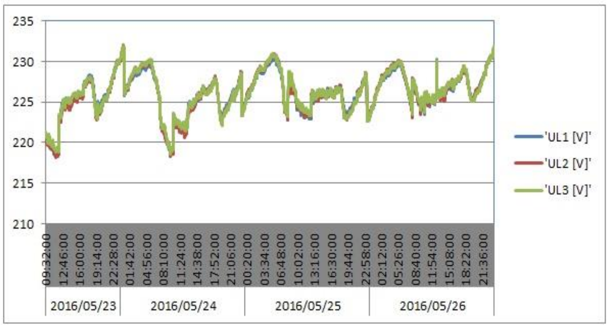

Fig.10 Voltage Variations of building after PV

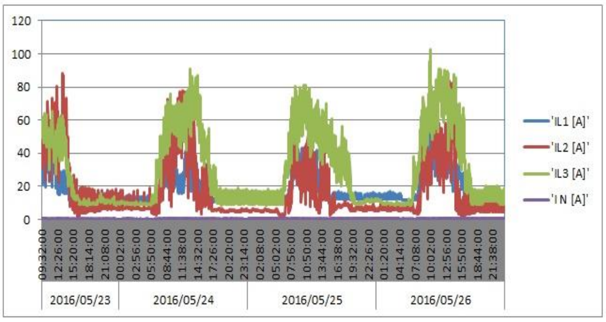

Fig.11 Current Variations of building after PV

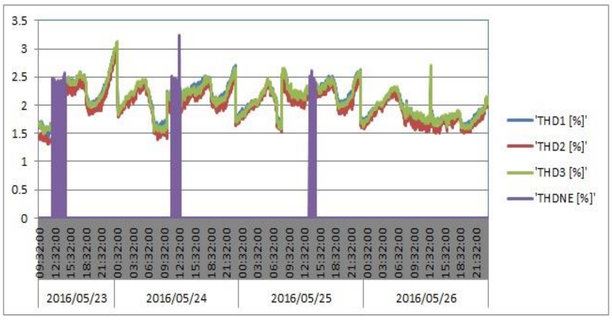

Fig.12 Voltage THD Variations of building after PV

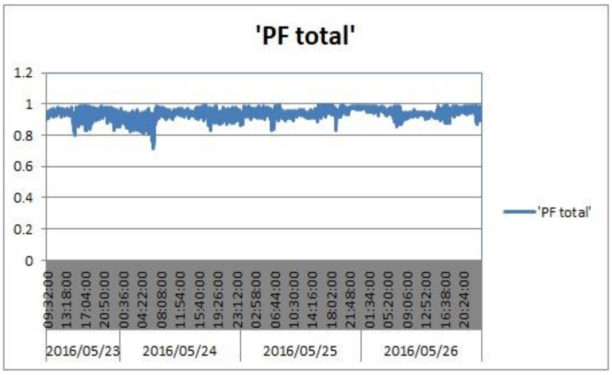

Fig.13 PF Variations of building after PV

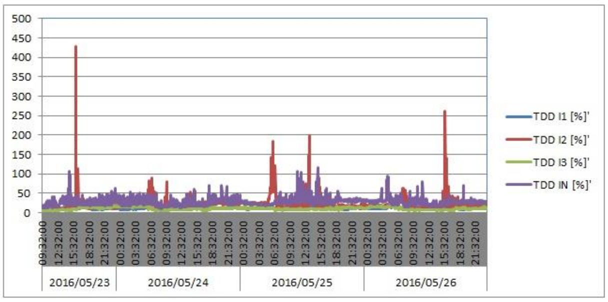

Fig.14 Current TDD Variations of building after PV

RESULTS AND ANALYSIS

Electric and magnetic field

All the measured magnetic flux density values in these head quarter were also far below the reference level for safe public exposure.

The measurements were carried in summer. The generated power varied from 15.6 kW to 17.66 kW during this period. The measured values at the PV positions on the roof were between 898 nT and 2214 nT. This maximum value on the roof was at the back of inverter room, for that the maximum magnetic field value was measured at the inverter position, outside the roof and it was equal to 1327 nT. The electric field measured values were between 0.84 V/m and 27 V/m, the maximum value 27 V/m was near the power cables collector tray.

Electrical parameters

The measurements conducted in this paper resulted in some notes listed as follows based on the analysis of the measurements over the building before and after installing PV as follows:

- ✓ Voltage variation according to Egyptian code is ±5% of nominal voltage, so all values of voltage are not out of standard limits in cases before and after installing PV.
- ✓ Values of TDD_I and THD_V after installing PV are within the limits of IEEE.
- ✓ There was current unbalance which reached 61% and this problem was solved by redistributing the load at maximum load of the building.
- ✓ Power factor variation is not less than 0.92 according to Egyptian code.
- ✓ The percentage of PV capacity is 5% of the total transformer distribution capacity.

The TDD_I in neutral conductor is greater by 3% before installing PV than after installing PV due to the current unbalance for the building loads which is above the limits, and the loads were be redistributed.

CONCLUSION

Electric and magnetic field

The measured electric field strength values in all cases were extremely lower than the reference level for safe public exposure, which is equal to 5kV/m. Also, the measured magnetic field values remained far below the relevant reference level for safe public exposure for magnetic field even around the inverter while maximum value recorded was 48 μT in its room.

Finally, the conclusion derived is that the examined fields are so small values which are not dangerous and, therefore, are no cause for public concern from this green energy.

Electrical parameters

Using the PV as a self-consumption has no impact on power quality quantities. Values of TDD_I and THD_V are within the limits of IEEE except some values of TDD_I out of limits in case of light loads.

NDEDC had installed 12 solar stations within its scope and had done the same measurements on them before and after the installation of the PV as sequence process does in a case study in this paper measurements were found in range.

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