Commission Meeting Minutes

November 27, 2023
7:00 PM

25440 W Newberry Road
Newberry, FL 32669

QUORUM CHECK

Mayor	Jordan Marlowe
Commissioners	Mark Clark Rick Coleman Monty Farnsworth Tim Marden Tony Mazon
City Clerk	Judy Rice
City Attorney	Scott Walker
Staff:	
Assistant City Manager, Chief Financial Officer	Dallas Lee
Director of Parks & Recreation	Travis Parker
Director of Planning & Economic Development	Bryan Thomas
Assistant Director of Finance	Amanda Hagan
Principal Planner	Jean-Paul Perez
Senior Planner	Uma Sarmistha
Executive Assistant	Randa Paul
Absent:	
City Manager	Mike New

CALL TO ORDER

Mayor Marlowe called the meeting to order at 7:00 PM.

APPROVAL OF AGENDA

Motion to approve the Agenda was made by Commissioner Marden, Seconded by Commissioner Farnsworth.

Voting Yea: Commissioner Coleman, Commissioner Farnsworth, Commissioner Marden, Commissioner Mazon

MOTION PASSED 4-0

Commissioner Clark joined the dais at 7:01 PM.

INVOCATION

Mr. Tim Marden provided the Invocation.

PLEDGE OF ALLEGIANCE

Commissioner Marden led the pledge.

PRESENTATIONS
(Please limit presentations to 15 minutes)

1. **Commissioner Mazon Graduation from the Institute for Elected Municipal Officials II**

   Mayor Marlowe recognized Commissioner Mazon for graduating from the Institute for Elected Municipal Officials, Level II.

2. **Building Strong Communities Award**

   Dallas Lee, CGFO, SHRM-CP, CPM, Assistant City Manager, announced that Newberry received a Building Strong Communities Award from the Florida Municipal Electric Association awarded for the 9th consecutive year. Twenty Florida public power communities earned this 2023 award.

3. **2023 Christmas Plans**

   Travis Parker, Director of Parks, Recreation and Facilities, presented the 2023 Christmas Capital of Alachua County Plan. Details are available on the www.christmascapitalofalachuacounty.com website.

PUBLIC ANNOUNCEMENTS
(Please limit announcements to 2 minutes)

Lisa Darling spoke regarding Rental Facilities being stocked with supplies.

CONSENT AGENDA

4. **November 13, 2023, Commission Meeting Minutes**
5. **Payment Registers**
6. **Declare Surplus Items**

Motion to approve the Consent Agenda was made by Commissioner Mazon, Seconded by Commissioner Marden.

Voting Yea: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, Commissioner Marden, Commissioner Mazon

MOTION PASSED 5-0

PUBLIC HEARINGS AND ORDINANCES

7. Fiscal Year 2023 Final Budget Amendment

Resolution 2023-63, A RESOLUTION OF THE CITY COMMISSION OF THE CITY OF NEWBERRY, FLORIDA, ADOPTING FINAL AMENDMENTS TO THE FISCAL YEAR 2022-2023 BUDGET; AND PROVIDING FOR SEVERABILITY, CONFLICTS, AN EFFECTIVE DATE.

Amanda Hagan, CPA, CGFO, Assistant Director of Finance & Administration presented Resolution 2023-63, amending the final budget for Fiscal Year 2023, with a PowerPoint. This Resolution increases revenues and decreases expenses for the fiscal year ending September 30, 2023, in accordance with the actual transactions.

Motion to adopt Resolution 2023-63 was made by Commissioner Coleman, Seconded by Commissioner Marden.

Voting Yea: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, Commissioner Marden, Commissioner Mazon

MOTION PASSED 5-0

8. First Reading: Herb Marlowe and Whitehurst Annexation 37

Voluntary requests for annexation in two separate areas contiguous with the City of Newberry

Quasi-Judicial Public Hearing First Reading: Ordinances 2023-34 and 2023-35 of the City of Newberry, Florida, to voluntarily annex certain portions of unincorporated Alachua County regarding two requests: 02659-000-000 consisting of ±161 acres (Ordinance 2023-34, Whitehurst Cattle Co) and three contiguous parcels 02579-005-000, 02579-006-000, and 02579-007-000 consisting of ±29 acres (Ordinance 2023-35, Herb Marlowe); a cumulative ±190 acres.

Mayor Marlowe reviewed the quasi-judicial procedures and read through the presentation order.

Attorney Walker read Ordinance 2023-34 by title only.

Clerk Rice swore in Principal Planner Jean-Paul Perez; Senior Planner Uma Sarmistha; Director Bryan Thomas, AICP; Gerry Dedenbach, AICP, LEED AP, Executive Vice President, and Principal Planner, CHW Professional Consultants.

Mayor Marlowe asked for ex parte communication on both applications.

ROLL CALL

Voting Nay: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, and Commissioner Mazon.
Mayor Marlowe, non-voting, none.

Principal Planner Perez presented a PowerPoint of the staff overview and recommendation on both applications.

Gerry Dedenbach presented a PowerPoint for Whitehurst Cattle Co.

There was no third-party intervenor present.

Mayor Marlowe asked for public comment, there was none.

There was no cross examination or final arguments.

Attorney Walker advised the Commission that their decision must be based upon substantial and competent evidence.

> **Motion to approve Ordinance 2023-34, an application for annexation by Whitehurst Cattle Co, and to establish December 11, 2023, as the date of the enactment hearing was made by Commissioner Mazon, Seconded by Commissioner Clark.**

Mayor Marlowe asked for public comment. There was none.

> **Voting Yea: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, Commissioner Marden, Commissioner Mazon**
>
> **MOTION PASSED 5-0**

Attorney Walker read Ordinance 2023-35 by title only.

Attorney Walker advised the Commission that their decision must be based upon substantial and competent evidence.

> **Motion to approve Ordinance 2023-35, an application for annexation by Herb Marlowe, and to establish December 11, 2023, as the date of the enactment hearing was made by Commissioner Farnsworth, Seconded by Commissioner Mazon.**

Mayor Marlowe asked for public comment. There was none.

> **Voting Yea: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, Commissioner Marden, Commissioner Mazon**
>
> **MOTION PASSED 5-0**

9. Cold Storage FLUMA

A request for a small-scale Future Land Use Map Amendment from Residential Low Density to Commercial on ±0.28 acres

Legislative Public Hearing: First reading of Ordinance 2023-32/CPA 23-11, an application by I S Property Holdings, LLC to amend the Future Land Use Plan Map of the Comprehensive Plan by changing the future land use classification from Residential Low Density to Commercial on a site consisting of approximately 0.28 acres; identified by Alachua County Tax Parcel Number 02173-000-000.

Attorney Walker read Ordinance 2023-32 by title only.

Principal Planner Perez presented a PowerPoint of the staff overview and recommendation for this application.

Mayor Marlowe asked for public comment. There was none.

Discussion ensued.

Motion to approve Ordinance 2023-32 on first reading was made by Commissioner Marden, Seconded by Commissioner Mazon.

Mayor Marlowe asked for public comment. There was none.

Voting Yea: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, Commissioner Marden, Commissioner Mazon

MOTION PASSED 5-0

10. **Quasi-Judicial: City Hall/Cold Storage Rezone**

A request to rezone the City Hall and Cold Storage properties from Residential, Single-Family (RSF-2) and Commercial, Central Business District (C-CBD) to Public Facilities (PF) and Commercial, Central Business District (C-CBD) on a site consisting of ±1.93 acres.

Quasi-Judicial Public Hearing: First reading of Ordinance 2023-33/LDR 23-16, an application by the City of Newberry and I S Property Holdings, LLC to amend the Official Zoning Atlas of the City of Newberry by changing the zoning districts from Residential, Single-Family (RSF-2) and Commercial, Central Business District (C-CBD) to Public Facilities (PF) and Commercial, Central Business District (C-CBD) on property located at 25440 West Newberry Road and 98 Northwest 254 Street consisting of ±1.93 acres; identified by Alachua County Parcel Numbers: 02173-000-000 and 02174-000-000.

Mayor Marlowe confirmed no one had entered the room since he read the quasi-judicial procedures.

Attorney Walker read Ordinance 2023-33 by title only.

Principal Planner Jean-Paul Perez remained sworn in.

Mayor Marlowe asked for ex parte communication on the application.

ROLL CALL

Voting Nay: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, and Commissioner Mazon. Mayor Marlowe, non-voting, none.

Principal Planner Perez presented a PowerPoint of the staff overview and recommendation.

There was no third-party intervenor present.

Mayor Marlowe asked for public comment, there was none.

There was no cross examination or final arguments.

Attorney Walker advised the Commission that their decision must be based upon substantial and competent evidence.

Motion to approve Ordinance 2023-33 on first reading was made by Commissioner Coleman, Seconded by Commissioner Marden.

Mayor Marlowe asked for public comment, there was none.

Voting Yea: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, Commissioner Marden, Commissioner Mazon

MOTION PASSED 5-0

11. Quasi-Judicial: Tanglewood Preliminary Plat

A request for preliminary plat for Phase 1 of the Tanglewood Planned Development.

Quasi-Judicial Public Hearing, Resolution 2023-59/SD 23-08, a request by CHW Professional Consultants, agent, on behalf of Tanglewood Properties of Gainesville, LLC, owner, for preliminary plat of Phase 1 of the Tanglewood Planned Development; a portion of Alachua County Tax Parcels 01923-000-000 and 01923-008-000.

Mayor Marlowe confirmed no one had entered the room since he read the quasi-judicial procedures.

Attorney Walker read Resolution 2023-59 by title only.

Principal Planner Jean-Paul Perez remained sworn in. Clerk Rice swore in Gary Weseman, Tanglewood Properties of Gainesville, LLC; and Walker Owen, PE, CHW Professional Consultants.

Mayor Marlowe asked for ex parte communication on the application.

ROLL CALL

Voting Nay: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, and Commissioner Mazon. Mayor Marlowe, non-voting, none.

Principal Planner Perez presented a PowerPoint of the staff overview and recommendation.

Gary Weseman stated he was present to answer any questions.

There was no third-party intervenor present.

Mayor Marlowe asked for public comment, there was none.

There was no cross examination or final arguments.

Principal Planner Perez; Walker Owen, Project Manager for the application; and Gary Weseman responded to questions.

Discussion ensued.

Attorney Walker advised the Commission that their decision must be based upon substantial and competent evidence.

Motion to approve Resolution 2023-59 was made by Commissioner Clark, Seconded by Commissioner Coleman.

ROLL CALL VOTE

Voting Yea: Commissioner Clark, Commissioner Coleman, Commissioner Marden, Commissioner Mazon

Voting Nay: Commissioner Farnsworth

MOTION PASSED 4-1

12. Quasi-Judicial: Preliminary Plat: Magnolia Acres

A request for approval of a Subdivision, Preliminary Plat, known as Magnolia Acres.

Quasi-Judicial Public Hearing, Resolution 2023-55/ SD 23-10, a request by eda consultants inc., Agent on behalf of RRL Newberry Holding, LLC., for a Major Subdivision, Preliminary Plat. The project is approximately 80 acres containing 15 lots, generally located south of SW 15th Avenue and east of SW 226 St., Alachua County Parcel Numbers 02545-000-000.

A new individual entered the room, so Mayor Marlowe read the quasi-judicial procedures.

Attorney Walker read Resolution 2023-55 by title only.

Uma Sarmistha, Bryan Thomas, and Jean-Paul Perez remained sworn. Clerk Rice swore in Claudia Vega, Director of Engineering, eda consultants, inc.

Mayor Marlowe asked for ex parte communication.

ROLL CALL

Voting Nay: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, and Commissioner Mazon.
Mayor Marlowe, non-voting, none.

Senior Planner Uma Sarmistha presented a PowerPoint of the staff overview.

Claudia Vega stated that she was present to answer questions on the application.

Senior Planner Uma Sarmistha presented a PowerPoint of the staff recommendation.

There was no third-party intervenor present.

Discussion ensued. Uma Sarmistha, Bryan Thomas, and Jean-Paul Perez responded to questions.

There was no cross examination or final arguments.

Attorney Walker advised the Commission that their decision must be based upon substantial and competent evidence.

Motion to approve Resolution 2023-55 was made by Commissioner Mazon, Seconded by Commissioner Clark.

Mayor Marlowe asked for public comment, there was none.

Voting Yea: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, Commissioner Marden, Commissioner Mazon

MOTION PASSED 5-0

13. Quasi-Judicial: Barrington Replat Rehearing

Rehearing of a request for a replat of Lots 8 through 11 and 23 of the Barrington subdivision entitled Barrington Replat.

Quasi-Judicial Public Hearing: Resolution 2023-56/SD 23-09, a request by CHW Professional Consultants, Agent, on behalf of Hawley Family Holdings, LLC, Owner, for approval of the Barrington Replat final plat on noncontiguous land consisting of approximately 39.8 acres generally located at the northwest corner of Southwest 15 Avenue and Southwest 170 Street.

Mayor Marlowe confirmed no one had entered the room since he read the quasi-judicial procedures.

Attorney Walker read Resolution 2023-56 by title only.

Principal Planner Jean-Paul Perez remained sworn in.

Mayor Marlowe asked for ex parte communication on the application.

ROLL CALL

Voting Nay: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, and Commissioner Mazon.
Mayor Marlowe, non-voting, none.

Principal Planner Perez presented a PowerPoint of the staff overview and recommendation.

There was no third-party intervenor present.

Mayor Marlowe asked for public comment, there was none.

There was no cross examination or final arguments.

Discussion ensued.

Attorney Walker advised the Commission that their decision must be based upon substantial and competent evidence.

Motion to approve Resolution 2023-56 was made by Commissioner Marden, Seconded by Commissioner Mazon.

Mayor Marlowe asked for public comment, there was none.

Voting Yea: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, Commissioner Marden, Commissioner Mazon

MOTION PASSED 5-0

AGENDA ITEMS

14. Solar Farm Presentation by CHW and Florida Renewable Partners

Bryan Thomas introduced Scott Scovill, Project Director, Florida Renewable Partners, who presented a PowerPoint.

Discussion ensued.

Craig Brashier, AICP, CHW Director of Planning

Mayor Marlowe asked for public comment. Jeff Holcomb presented the Commission with two published studies regarding electromagnetic fields from solar farms. Lisa Darling, Travis Edmond, Michael Wyrick, Charlie Jackson, Joshua Wyrick, and Ann Coyne also spoke.

Scott Scovill responded to questions.

15. Champions Park Operations Renewal

Travis Parker, Director of Parks, Recreation and Facilities presented a PowerPoint overview and recommendation that the Commission authorize the City Manager to execute a contract with RADDSports for the continued management and operations of Champions Park.

Discussion ensued.

Motion to Table was made by Commissioner Marden, Seconded by Commissioner Clark.

Mayor Marlowe asked for public comment. Michael Wyrick spoke.

Voting Yea: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, Commissioner Marden, Commissioner Mazon

MOTION PASSED 5-0

16. Construction Manager Continuing Services Pool

Travis Parker, Director of Parks, Recreation and Facilities, presented a PowerPoint overview and recommendation that the Commission authorize the City Manager to piggyback on the University of Florida's continuing services contract, entering into contractual agreements with selected vendors to establish a dedicated pool of construction management resources for the City of Newberry.

Motion to authorize the City Manager to piggyback on the University of Florida's Construction Manager Continuing Services Pool was made by Commissioner Farnsworth, Seconded by Commissioner Coleman.

Discussion ensued.

Mayor Marlowe asked for public comment, there was none.

Voting Yea: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, Commissioner Marden, Commissioner Mazon

MOTION PASSED 5-0

17. Alachua County Public School Rezoning Initiative.

Dallas Lee presented a PowerPoint for this item.

Motion to transmit a letter to the School Board of Alachua County (SBAC), signed by the Mayor and containing recommendations for rezoning plans, was made by Commissioner Marden, Seconded by Commissioner Mazon.

Mayor Marlowe asked for public comment, there was none.

Voting Yea: Commissioner Clark, Commissioner Coleman, Commissioner Farnsworth, Commissioner Marden, Commissioner Mazon

MOTION PASSED 5-0

18. Legal Services

Mayor Marlowe introduced the item.

Discussion ensued.

By consensus, the Commission agreed to forego bidding for legal services.

Scott Walker thanked the Mayor and Commission.

COMMENTS

Assistant City Manager Lee, City Attorney Walker, Commissioner Clark, Commissioner Farnsworth, Commissioner Mazon, and Mayor Marlowe made comments.

A resident inquired about hosting the City of Gainesville's Medieval Festival in Newberry. Mayor Marlowe responded that he is in discussion regarding potential Newberry locations for 2025.

MEETING ADJOURNMENT

The meeting adjourned at 10:22 PM.

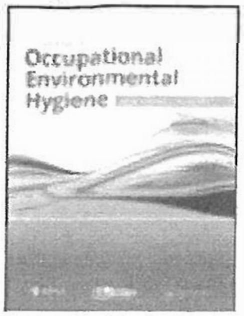
Signed and approved on this 11th day of December 2023.

Jordan Marlowe, Mayor

Judy S. Rice, City Clerk

Attachment A: Electromagnetic Fields Associated with Commercial Solar Photovoltaic Electric Power Generating Facilities (Item 14, Holcomb handout)
Attachment B: Measurement and Analysis of Electric and Magnetic Field Strength in Grid-Tied Photovoltaic Power System Components (Item 14, Holcomb handout)

Attachment A, Item 14, Holcomb handout



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Electromagnetic Fields Associated with Commercial Solar Photovoltaic Electric Power Generating Facilities

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[3]Southern California Edison Company, Rosemead, California
[4]Exponent, Menlo Park, California
[5]Electric Power Research Institute, Palo Alto, California

The southwest region of the United States is expected to experience an expansion of commercial solar photovoltaic generation facilities over the next 25 years. A solar facility converts direct current generated by the solar panels to three-phase 60-Hz power that is fed to the grid. This conversion involves sequential processing of the direct current through an inverter that produces low-voltage three-phase power, which is stepped up to distribution voltage (~12 kV) through a transformer. This study characterized magnetic and electric fields between the frequencies of 0 Hz and 3 GHz at two facilities operated by the Southern California Edison Company in Porterville, CA and San Bernardino, CA. Static magnetic fields were very small compared to exposure limits established by IEEE and ICNIRP. The highest 60-Hz magnetic fields were measured adjacent to transformers and inverters, and radiofrequency fields from 5–100 kHz were associated with the inverters. The fields measured complied in every case with IEEE controlled and ICNIRP occupational exposure limits. In all cases, electric fields were negligible compared to IEEE and ICNIRP limits across the spectrum measured and when compared to the FCC limits (≥0.3 MHz).

Keywords electric fields, exposure standards and guidelines, magnetic fields, solar photovoltaic power

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/uoeh.

INTRODUCTION

The electric power-generating portfolio within the United States (U.S.) and around the world is undergoing a shift toward a greater reliance on renewable sources. Based on 2013 statistics available at the US Department of Energy (DOE) Energy Information Administration's (EIA) website (http://www.eia.gov/), renewables in 2014 will account for about 500 billion kW–h or ~13% of net power generation to the grid in the U.S., which totals nearly 4,000 billion kW–h on an annual basis (EIA, 2013). The EIA projects this fraction to rise to about 750 billion kW–h or ~16% of nearly 5,000 billion kW–h annually by 2040.

However, given geographically heterogeneous mixtures of natural resources (e.g., solar, wind, and geothermal energy) and the unique manner in which renewables will be deployed within each of the U.S.'s 50 states (30 of which have legislated mandates for Renewable Portfolio Standard or RPS), national averages provide only order of magnitude estimates of the nation's resource mix with no reflection of local trends. The North American Electric Reliability Corporation (NERC) is charged by the Federal Energy Regulatory Commission (FERC) to monitor and work to assure electric reliability across North America; NERC splits its oversight into 22 reliability regions. As an example of locale-specific energy portfolios, of these 22 NERC regions, the EIA projects that geothermal will exceed 30% of the renewable portfolio after 2030 in one region (Western Electricity Coordinating Council (WECC)/California (CA)). On the other hand, hydropower is and will continue as the dominant renewable resource in the northwest (WECC/NW Power Pool).

Solar photovoltaics (PV) presently account for about 6.8 billion kW–h or ~1.4% of renewable generation in the US, expected to rise to about 56.2 billion kW–h or ~7.5% of renewable generation nationwide by 2040. However, by 2040 over 95% of solar PV generation is expected to be concentrated in four regions, with the highest share of all PV (~43%) in the WECC/CA region; today this region accounts for about 45% of 6.7 billion kW–h PV nationwide.

The basic components of a solar PV facility (Figure 1) include the panel array that converts energy from sunlight to direct current (DC) electricity, fed through a fusebox to the inverter, which chops the dc and conditions the power into 3-phase, 60-Hz sinusoidal voltage and current. A transformer steps up the "low-voltage" inverter output (~120 V per

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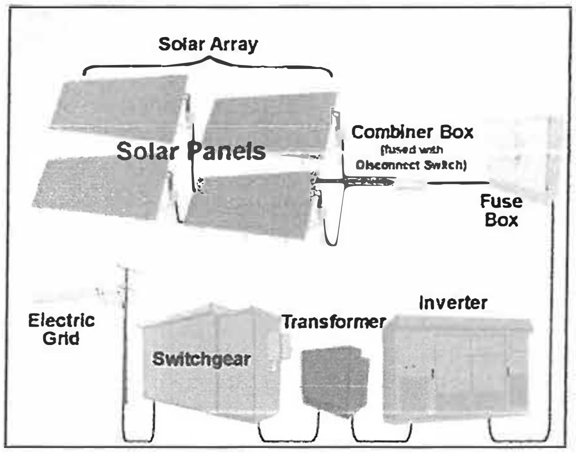

FIGURE 1. Basic components of a commercial solar photovoltaic facility (described in text).

phase or ~208 V phase-to-phase) to the voltage used by the distribution system grid (e.g., ~12 kV phase-to-phase). A switchgear unit manages the flow of electrical power from the transformer to the grid.

Prudence suggests that when a new technology is in its early phase of expansion, a proactive effort to characterize the environmental factors associated with that technology is advisable. This article describes measurements of the electromagnetic environment conducted at two commercial solar PV facilities operated by Southern California Edison Company. The measurements covered extremely low-frequency (ELF) and the radiofrequency (RF) bands, as well as static (dc) fields. This article presents the data most relevant to an evaluation of compliance of the measured fields with exposure limits published by the Institute for Electrical and Electronic Engineers (IEEE) and the International Commission on Non-Ionizing Radiation protection (ICNIRP).[1–4] Further detail is available in a technical report published by the Electric Power Research Institute.[5]

METHODS

Study Sites

SCE's Porterville facility covers 32 acres and consists of 29,400 individual solar panels. The facility is comprised of ten sections, five on the northern side and five on the southern side, each of which can produce up to 500 kW. In addition to the solar panels with ancillary electronics located in a "J"-Box attached beneath them, each section includes (1) a fuse box, and (2) an inverter and a transformer located at a corner of each section (at the southwestern corner for northern sections and at the northwestern corner for southern sections). AC electric power at 12-kV from each section's transformer is routed through underground cables to the farthest southwestern section where the main switchgear for the entire facility is located. Electrical power is then routed via underground cables from the switchgear to the overhead electrical grid located along the main road west of the facility. The overhead view of the Porterville facility (Figure 2) indicates the two locations selected for measurement of power frequency fields; these are shown as Location #1 with a "typical" inverter/transformer unit, and Location #2, which is additionally equipped with the switchgear unit to feed the grid. The Porterville facility went into service in February 2011. It was visited twice for this study, first on November 29, 2011, when the weather was extremely overcast with the facility operating at less than 10% of capacity. It was revisited in clear weather on July

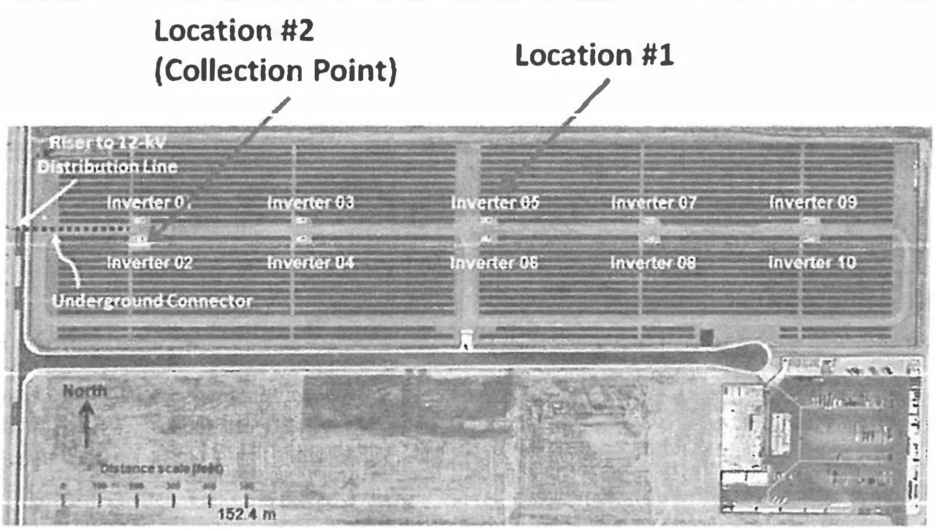

FIGURE 2. Overhead view of the 10 sections of the Porterville solar farm indicating Location #2 where the switchgear feeds the grid. Locations #1 and #2 were the primary sites for DC to ELF measurements. RF measurements were focused on the inverters across the facility.

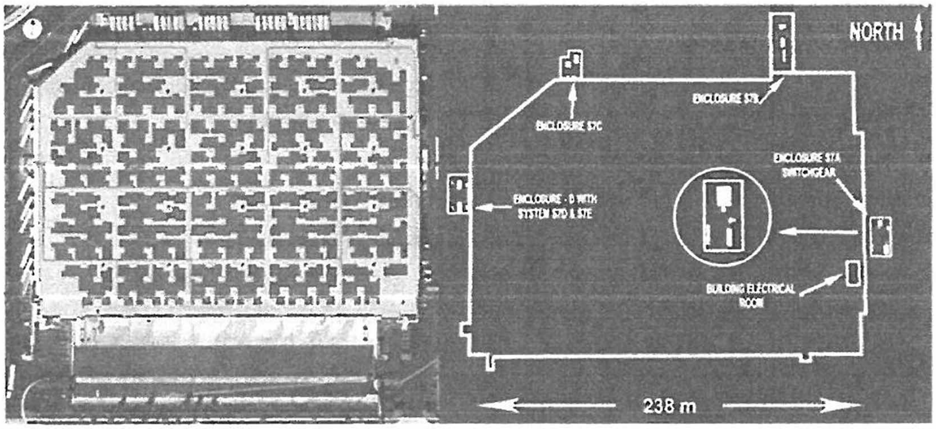

FIGURE 3. Overhead view and schematic drawing of the rooftop solar farm in San Bernardino indicating the four enclosures at ground level. The eastern enclosure (on the right) contains the switchgear that feeds the grid.

24, 2012 when the facility was operating at 90 ± 10% of capacity.

The San Bernardino facility is a 10-acre (0.040 km^2) rooftop farm (Figure 3) with a roof height of approximately 9.1 m above ground. It consists of four sections each of which feeds an enclosure at ground level, one on the west side, two on the north and one on the east. The enclosures are each equipped with an inverter and transformer identical to those at the Porterville farm (i.e., up to 500 kW per section). The eastern enclosure also contains the switchgear that collects power from all four sections. The west and north enclosures receive DC input from their respective sections on the rooftop via a vertical cable along the exterior building wall, and return AC back to the rooftop vertically along the same wall where they converge with the fourth AC cable on the rooftop and together feed the eastern enclosure. Field measurements were conducted on the roof of the building and inside the four inverter/transformer "cages" at the east end of the building. (The building's interior was not visited.) The San Bernardino farm went into service in January 2012. It was visited under clear conditions on May 14, 2012, when it was operating at near full capacity.

The specifications for the equipment at the Porterville and San Bernardino facilities are provided in Tables I–III.

Instrumentation

DC magnetic field: For static (0 Hertz) DC magnetic field measurements, a Bartington MAG-03MC1000 sensor probe was used. The MAG-03MC1000 is a handheld, three-axis DC magnetic field fluxgate probe but does have a bandwidth response up to 3,000 Hz with a measurement range up to 1.0 millitesla (mT) and accuracy of about ±0.5%. The EMDEX WaveCorder is a hand-held AC magnetic field waveform measurement device, which samples, stores, displays, and allows analysis of the wave representing the time varying AC magnetic field up to 3 kHz. For the results reported here the Wavecorder received magnetic field measurement data from the Bartington 3-axis sensor and recorded these data to a file at a sample rate of approximately once every 1.5 sec. The WaveCorder sampling rate is 15,360 samples per second over a pre-defined measurement period, and displays/records the resulting waveform, with an accuracy of about ±2%.

Power frequency magnetic field: The EMDEX II Magnetic Field Digital Exposure Meter was used to measure 60-Hz magnetic fields and their wideband harmonic content over a 40–800 Hz frequency range. The EMDEX II records the rms (root-mean-squared) field components sequentially

TABLE I. Solar Photovoltaic Module (Panel) Specifications

	Porterville	San Bernardino
Manufacturer	Trinasolar	Sunpower
Max Power	230W	230 W
Max Power – Voltage	30V DC	
Max Power – Current	7.66A DC	
Max System Voltage	600V DC	

TABLE II. Inverter Specifications for Porterville and San Bernardino

Manufacturer	Satcon Technology Corporation
Input Voltage	Maximum: 600V DC
Input Current	Maximum: 1610A DC
Output Voltage	Nominal: 200V 3-Phase AC
Output Current	Maximum: 1444A AC

TABLE III. Transformer Specifications for Porterville and San Bernardino

Manufacturer	HO
Power Rating	500 KVA
High Voltage	12 kV Delta
Low Voltage	208Y/120
Output Power – Maximum	500 kW

from three mutually orthogonal axes (x, y, and z) and calculates the rms vector magnitude field, B_R:

$$B_R = \left(B_x^2+B_y^2+B_z^2\right)^{0.5}$$

The EMDEX II meter measures from 0.01 μT to 0.3 mT with an accuracy of ±2%. For this study, the EMDEX II was programmed to record the magnetic field once every 1.5 seconds; in other words there is an interval of approximately 0.5 s between the acquisition of x-, y-, and z-axis readings.

Power frequency electric field: An EMDEX II meter was also used in conjunction with an E-PROBE field sensor to measure electric fields (40–800 Hz). The E-PROBE is a parallel-plate electric field sensor attached to an insulated fiberglass handle. The EMDEX II meter is placed between the two sensing plates of the E-PROBE and is connected to them via an external cable to record the electric field. The E-PROBE has a range of 10 V/m to 13 kV/m, with a resolution of 1 V/m and typical accuracy of ±5%. At each measurement point adjacent to equipment not previously encountered by the person administering the measurement (HCH) such as "J"-Box, combiner box, fuse box, the E-PROBE was rotated in a three-axis manner to capture the orientation with the maximum electric field. Extensive experience of this individual with transformers, inverters and switchgear (unpublished) indicated that the electric field would assume a vertical orientation. Regardless, at heights within 1.0–1.5 m of the ground plane—the height range most appropriate for compliance evaluation—the unperturbed electric field will tend to a vertical orientation (normal to the ground plane) with maximal coupling to a vertically oriented person.

RF Measurements

Low-Frequency (LF) Electric and Magnetic Fields (<100 kHz): Fields in this band were measured with a Narda model EHP-50C, initially, and, subsequently, model EHP-50D Electric and Magnetic Isotropic Field Analyzer. This device provides for simultaneous measurement of the x-, y-, and z-axis field rms vector components and calculates the resultant field using the Fast Fourier Transform (FFT) digital signal processing software executed on a connected laptop (i.e., the resultant equals the rms vector magnitude). A wideband value of field is provided by the EHP-50 by summing of the magnitudes of the frequency components across the measured spectrum.

The EHP instrument covers the frequency range of 5 Hz to 100 kHz, making it ideal for detection of the 5 kHz switching frequency of the inverters. Measurements were performed by manually surveying the area near the different solar equipment components by carrying the EHP-50 instrument using a supplied dielectric handle to isolate the instrument from the user. Each measurement was taken over a period of several seconds; during this time, virtually no changes in field values were observed. This observation was expected since the operation of the solar facilities was essentially steady-state with no rapidly changing outputs from the solar arrays that would result in acutely variable inverter outputs.

Intermediate Frequency (IF) Electric Fields: Electric fields from 100 kHz to 30 MHz were measured using two versions of a monopole antenna (AH Systems model SAS-550-1B Active Monopole, SN 854 and 865; AH Systems model SAS-551 Passive Monopole, SN 193). The model SAS-550-1B is designed to cover the frequency range of 9 kHz to 60 MHz and the model SAS-551, 9 kHz to 40 MHz. Measured signal levels as observed on the spectrum analyzer were adjusted for the antenna factor provided by the manufacturer to obtain the electric field strength. In each case of using one of the monopole antennas, a spectrum analyzer (Narda model SRM-3006, see below) was used as the detection device connected to the respective monopole. For each measurement band, the resolution bandwidth (RBW) of the spectrum analyzer was set to adequately resolve most individual signal contributions. In the 10 kHz to 100 kHz band, the RBW was set to 50 Hz; in the 5 kHz to 30 MHz band, the RBW was set to 10 kHz; in the 26 MHz to 3 GHz band, the RBW was set to 1 MHz. Electric fields were measured by extending the telescoping monopole element to its full length of 104 cm (41 in) in a vertical orientation and connecting it to the BNC connector on the top of an electronics box in the center of the 46 cm square by (18 in x 18 in) square ground plane. Initial measurements with the active monopole were performed by attaching the ground plane to a nonconductive tripod such that the ground plane was at a height of 1 m above ground. Subsequent to the initial Porterville measurements, the monopole antenna measurements were conducted by placing the antenna directly on the ground or concrete pad upon which equipment was mounted (this approach captured the vertical orientation of the electric field). For IF RF electric field measurements, the vertical orientation of the monopole was appropriate to capturing the most relevant polarization component of emitted electric fields in terms of potential specific absorption rate (SAR) within the body. For example, at 1 MHz, the SAR in the body of the average man caused by an electric field parallel with the body axis results in 13 times the energy absorption rate of that produced by exposure to the same magnitude field perpendicular to the body.[(6)] This means that the single polarization field measurements cannot be directly compared to the exposure limits but it was deemed that contributions to the total electric field from other than the

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vertical component, which would result in the greatest internal electric field within a standing individual, would not be significant relative to evaluating compliance with the limit.

Higher Frequency RF Fields: A Narda model SRM-3006 Selective Radiation Meter (SN D-0069) was used for measurements of fields from 26 MHz to 3 GHz. This instrument makes use of an isotropic probe/antenna and displays measured rms vector magnitude RF field strengths in terms of a percentage of the Federal Communications Commission (FCC) maximum permissible exposure (MPE) for the general public.(7) The spectrum analyzer portion of the measurement system makes use of FFT technology to display measured fields as a function of frequency with the resultant field being the root-sum-squared value of the three orthogonal components (sequentially detected over a time span of less than 100 milliseconds) as detected by the probe/antenna. When the basic spectrum analyzer unit is used in conjunction with an external antenna, such as one of the monopoles described above, the signal level is indicated in terms of power (dBm) or voltage (dBμV) to which the relevant antenna factor is added to obtain electric field strength.

RESULTS

DC

The background static magnetic field at the Porterville and San Bernardino facilities had measured resultant values of 51.6 μT and 61.5 μT, respectively. These values are different from those available from websites such as www.ngdc.noaa.gov because the infrastructure and equipment of the PV installation distort the geomagnetic field. Measureable DC fields were recorded adjacent to equipment carrying direct current including the cables leading from the solar panels through the combiner box to the fuse box; the fuse box itself; and the DC current pathway to the inverter and the inverter itself. Values cited for Porterville represent the facility operating between 4.0 and 4.9 MW (near full capacity). Directly adjacent to the DC cables at either facility, a maximum field of 0.103 mT was recorded in Porterville (Location #1). The field adjacent to the fuse box reached a maximum of 0.171 mT, again at Porterville (Location #1). The maximum field around the perimeter of an inverter was 0.277 mT recorded also in Porterville (Location #1). The DC fields in San Bernardino at equivalent locations were only moderately lower than those reported for Porterville. Note that these measurements did not differentiate between the DC magnetic field attributable to sources within the facilities and the geomagnetic field. Thus, in the case of opposing vectors, for example, the maximum field due only to the inverter could have conceivably been over 0.3 mT. In fact, on the south side of the rooftop, the measured fields were below ambient field levels directly adjacent to the DC cables (33.3 μT) and rose toward the ambient value with increasing distance from the cables. Also note that elevated DC fields were observed adjacent to the transformers because their iron cores concentrate the geomagnetic field's flux lines, with a maximum field of 0.258 mT recorded at Porterville (Location #1). However, transformers at power facilities everywhere concentrate the geomagnetic field's flux lines, as do virtually all other large iron objects.

Power Frequency and Harmonics

Power frequency electric fields were practically non-existent reaching 16 V/m and 10 V/m directly adjacent to a transformer and inverter, respectively, in San Bernardino. The field decayed to 0 V/m within 30 cm of these units. Since the connection between the switchgear and the 12-kV distribution line was underground, the corresponding electric field was negligible (the electric field beneath the 12-kV line was not recorded).

In the pathway leading from the solar panels through the combiner box to the inverter, the highest wideband AC magnetic field of 4.9 μT rms was measured directly adjacent to the "J"-Box (Porterville, Location #1), which as described above, is equipped with AC-powered electronics. The field diminished to 0.6 μT rms 30 cm away. The "J"-Box's field spectrum showed 71% and 25% of its power at 60 Hz and 120 Hz, respectively. The magnetic field directly around the perimeter of the fuse box had a maximum value of 4.7 μT rms, but the fields around the fuse box were likely influenced by a nearby transformer, and possibly an inverter; a spectrum was not recorded because of the presence of these other sources.

On the "AC" side of the system, the AC fields measured at the inverter, transformer, switchgear and AC power cables (leading underground from the switchgear to the grid) were comparatively greater, with $\geq$99% of the spectral power concentrated at 60 Hz. To illustrate the effect of prevailing weather conditions, Figure 4 illustrates the 60-Hz magnetic field profile leading from the inverter at Location #1 in Porterville under cloud-covered conditions (nominally 350–450 kW) and clear conditions (nominally 4–4.9 MW). For the latter, the field measured directly adjacent to the inverter was 110 μT, and for the former, 29 μT, tailing off with distance in both cases; within 1 m, the field was $<$10 μT. The profile from the transformer to the inverter at Location #2 (Figure 5) indicates a similar pattern with 14.7 μT and 177 μT directly adjacent to the transformer under cloudy and clear conditions, respectively; within 1 m, the field fell to $<$10 μT. The small uptick further out reflects the influence of the inverter.

At the rooftop facility, the highest AC (60-Hz) magnetic fields were measured in the eastern enclosure where the AC from all four sections feed the switchgear. Readings were taken along the profiles leading from the inverter and from the transformer. The fields directly adjacent to the transformer and inverter were 96 μT and 113 μT, respectively, falling to $<$10 μT within 1 m (Figure 6). Magnetic field measurements were also conducted near the AC power cable at the northeast collection area of the rooftop, leading from the cable to a relatively open area. The magnetic field was 41 μT rms directly

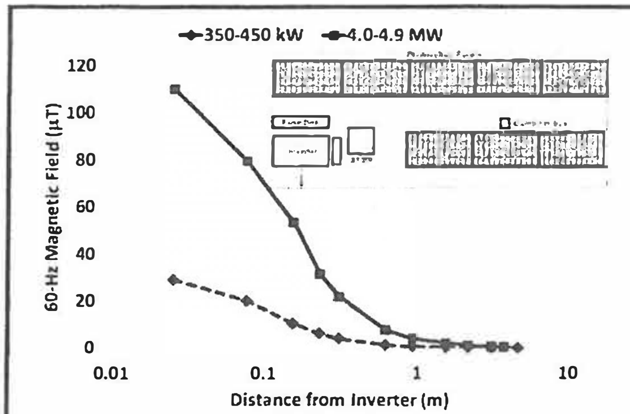

FIGURE 4. Profile of 60-Hz magnetic field leading from the inverter at Location #1 in Porterville (see inset). Measurements were taken in November 2011 under cloudy conditions with the facility operating between about 350–450 kW (broken line), and during clear conditions in July 2012 (solid line).

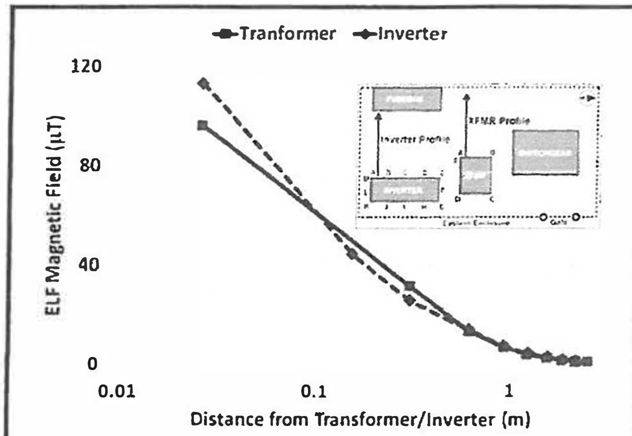

FIGURE 6. Profile of 60-Hz magnetic field leading from the transformer and the inverter in the eastern enclosure in San Bernardino (see inset).

adjacent to the cable and decayed as $1/r$ to $<0.3\ \mu T$ about a meter away. It is unlikely that there was any appreciable exposure from this source inside the building.

Radiofrequency

All of the radiofrequency fields due to the farms' operations were attributable to the insulated gate bipolar transistor (IGBT) switching circuitry within the inverters. During the first Porterville visit the switching spectrum was recorded with the EHP-50D indicating switching activity at nominally 5 kHz (Figure 7). Spectral peaks were detected at 4.750, 4.875, 5.125 and 5.250 kHz. However, the resolution bandwidth of the spectrum analyzer was 25 Hz for this measurement and may not exactly represent the actual frequencies.

Wideband 5–100 *kHz* magnetic and electric fields were measured at Porterville's Inverter #10 with the EHP-50D with the unit operating nominally at between 400 and 490 kW (clear weather). The highest field of 40 μT was recorded at the front face of the inverter, falling to $<0.1\ \mu T$ 1.5 m away (Figure 8, top). At the first Porterville visit (cloudy day) at Inverter #6 operating at 42 kW, the maximum reading was 0.68 μT, with a more gradual percent fall-off with distance (0.12 μT at 3 m). The wideband electric field was 1.4 V/m at the face of Inverter #10 falling to 0.4 V/m about 0.3 m away (Figure 8, bottom). The magnetic field spectra at Porterville during the second visit show virtually identical patterns at the face of all 10 inverters (data not shown). For the electric field all spectra were the same except for Inverter #8 for which there is no apparent explanation (data not shown). Similar field characteristics were

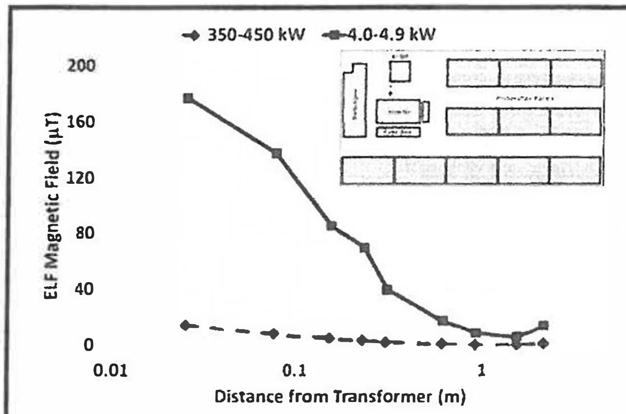

FIGURE 5. Profile of 60-Hz magnetic field leading from the transformer at Location #2 in Porterville (see inset). Measurements were taken in November 2011 under cloudy conditions with the facility operating between about 350–450 kW (broken line), and during clear conditions in July 2012 (solid line).

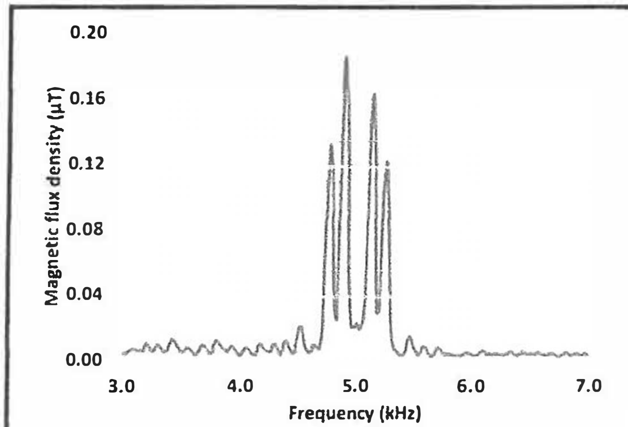

FIGURE 7. Spectrum associated with the nominal 5-kHz switching operation of Inverter #5 at Porterville measured during the first visit (November 2011).

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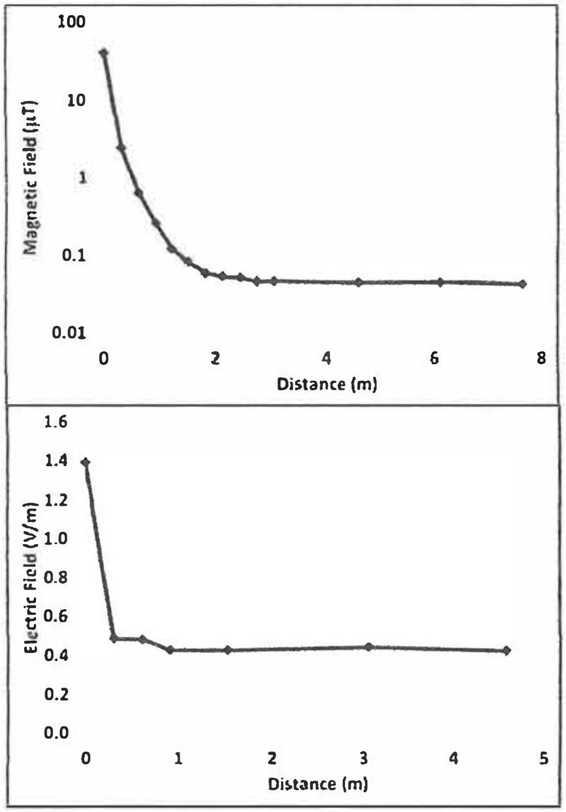

FIGURE 8. Wideband (5-100 kHz) magnetic (top) and electric (bottom) field profiles from Inverter #10 in Porterville during the second visit in July 2012 (clear conditions).

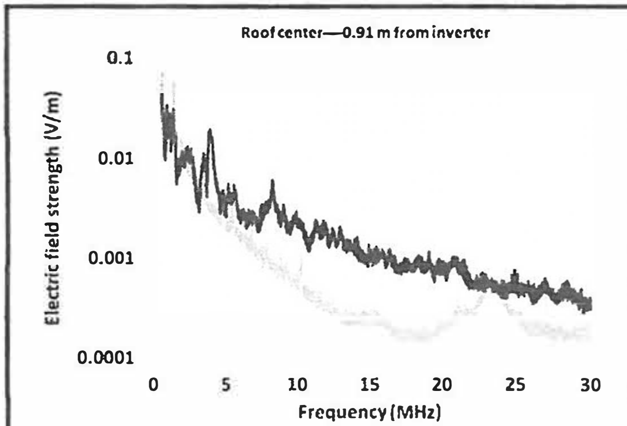

FIGURE 9. Electric field spectra on roof of San Bernardino farm and 1 m from the inverter in the eastern enclosure (0.5–30 MHz).

observed at the San Bernardino facility across the 0–100 kHz spectrum (data not shown).

With the monopole antenna (0.5–30 MHz) at the second Porterville visit, the electric fields remained <0.1 V/m across the frequency band beyond 0.5 m from Inverter #5 (Figure 9). Similarly, at the San Bernardino facility, the electric field across the band was less than 0.1 V/m 1 m from the inverter, as well as at the center of the roof, which was predominantly lower. Thus, very low power densities from 0.5–30 MHz were detected at both facilities.

In the 26 MHz to 3 GHz band, the fields were attributable to broadcast and cellular phone downlink activity, with virtually none attributable to either facility (outside of any local cellular transmission or other wireless communication).

DISCUSSION

This investigation has characterized the electromagnetic environment of two commercial solar photovoltaic generation facilities between 0 Hz and 3 GHz. The investigators acquired measurement data at representative locations of potential field sources at these facilities. However, given a total area of 0.17 km^2 (42 acres) for both farms combined, the goal of the measurement exercises was not to cover all possible locations within the facilities. Nonetheless, with the sources measured at both facilities during clear and sunny weather providing results consistent with each other—given a moderately lower power generated at San Bernardino, compared to Porterville—the investigators are highly confident that these measurements represent the electromagnetic environments at these sites. Whether the results may be generalized to other solar generation facilities cannot be definitively stated, but other facilities with similar equipment would be expected to yield results at the same order of magnitude as the fields reported here.

As public access to these facilities is restricted, the primary interest of this investigation was to benchmark the ambient fields measured against the "controlled" exposure limits published by IEEE and the 'occupational' limits published by ICNIRP. While both designations are similar, "controlled" implies an environment in which employees have been trained to be aware of the electromagnetic environment in their workplace. The term "occupational" is not fully defined by ICNIRP, and could be generalized to include all workers, trained or not.

Measurements of a Trinasolar photovoltaic panel conducted along a profile from the end of a section of panels towards an open area between panel sections (at Porterville) showed no evidence of DC magnetic field or AC electric or magnetic fields (data not shown).

Measured DC fields did not exceed 0.3 mT, with readings at about this level adjacent to an inverter and a transformer. IEEE's "controlled" limit for DC magnetic fields is 0.353 T, and 0.118 T for the general public. ICNIRP's occupational limit is 2 T for occupational exposure and 0.4 T for the general public.[8] Thus, the maximum DC fields measured are about 1,200 times lower than IEEE's "controlled" limit, and 7,000 times lower than ICNIRP's occupational limit; these fields are also about 400 (IEEE) and 1,300 (ICNIRP) times lower than the general public limits. However, within 2–3 m away, the fields drop to background levels. In addition, and as mentioned in the Results, DC magnetic fields of the magnitude measured adjacent to the inverters in this study would also be

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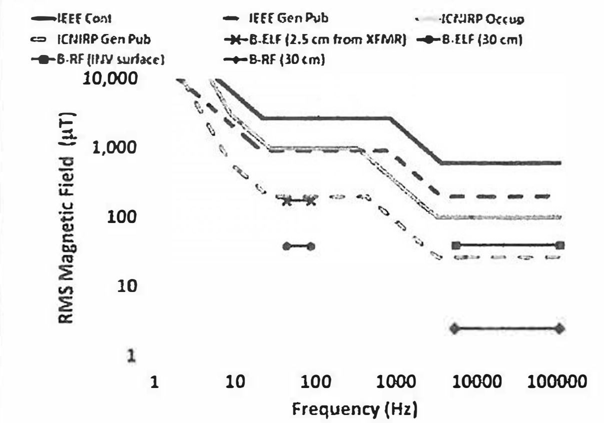

FIGURE 10. Maximum 60 Hz and RF magnetic fields in the context of IEEE's controlled (solid black line) and general public (broken solid black line) and ICNIRP' occupational (solid open line) and general public (broken open line) exposure limits. Maximal readings of 60 Hz (x) and wideband (■) (5–100 kHz) magnetic fields were measured adjacent to a transformer (SFMR) and inverter (INV), respectively in Porterville. Field levels are shown 30 cm from the transformer (•) and the inverter (♦). (Cont, controlled; Gen Pub, general public; Occup, occupational; B-ELF, 60 Hz magnetic field; B-RF, radiofrequency magnetic field).

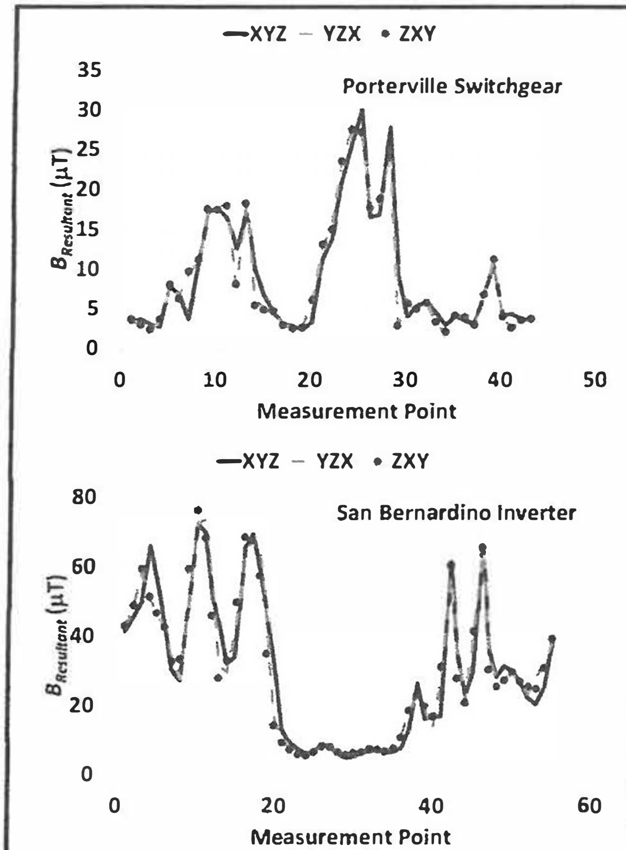

FIGURE 11. Perimeter profiles around the switchgear in Porterville (top) and the inverter in San Bernardino (bottom). XYZ refers to sequence of actual data acquisition along the three coil axes in the EMDEX II (base case). YZX and ZXY reflect the outcome if, instead, the cycle began with the y-coil and z-coil, respectively. The individual taking the measurements maintained an approximately steady walking pace around the equipment.

present adjacent to any high power transformer because of the transformer core concentrating the field.

For frequencies between 40 Hz and 800 Hz wideband electric fields across both facilities were negligible to non-detectable. From 5–100 kHz vertically polarized fields up to 1.4 V/m were measured directly adjacent to one face of an inverter at Porterville. These fields are well below values that would be expected to produce SARs exceeding basic restrictions in both ICNIRP and IEEE exposure limits for occupational or general public exposure (Figure 10), and by 0.3 m away from the face of the inverter had dropped to background levels.

Electric fields were characterized across the spectrum up to 3 GHz. From 26 MHz to 3 GHz, the only presence of RF was from broadcast and wireless communications at levels far lower than the limits specified by the Federal Communications Commission, which regulates these frequencies.

The maximum 5–100 kHz wideband field measured was 40.5 μT at the face of an inverter in Porterville, 15- and 2.5-fold lower than the IEEE controlled and ICNIRP occupational exposure limits, respectively. The field directly at the inverter exceeded the ICNIRP limit for the general public of 26.8 μT, but at 30 cm, the field had fallen off to 2.5 μT, more than 10-fold lower than ICNIRP's general public limit. At 60 Hz, the highest magnetic field measured was 177 μT directly adjacent to a transformer in Porterville. This field is 15- and 5.6-fold lower than the IEEE controlled and ICNIRP occupational exposure limits, respectively; this level is close to ICNIRP's general public limit of 200 μT. However, at 30 cm from the transformer surface, the field dropped to 39.7 μT.

With regard to the 60-Hz magnetic field measurements, the EMDEX II used in this study acquires rms magnetic field readings in the 40–800 Hz band serially along three mutually orthogonal axes. For this study, the monitor was set to its highest specified rate to record x-, y-, and z-axis readings and to store these data every 1.5 s; thus, each axis acquired its respective field reading over a period of about 0.5 s. A question arises as to whether such delay could significantly bias the results presented in this paper, relative to data simultaneously acquired (hypothetically) on all three axes. Conceptually, such bias would be evident with an environment in which the fields were changing significantly within the three-axis time cycle. To address this issue more specifically within the PV facilities, two examples are presented, although the results were essentially the same for all 28 profiles and perimeter measurements that were taken in all. In the base case, the field resultants were based on data acquired in an x-y-z sequence (XYZ). Using the raw data, the data collections were altered to occur in a y-z-next x sequence (YZX), and in a z-next x-next y sequence (ZXY). The results for perimeter measurements around the Porterville switchgear and the San Bernardino inverter (Figure 11) indicate little overall differences in the profile, despite the fact that the individual conducting the measurements maintained a steady pace, and the differences among the three profiles in each case could have arisen from spatial factors independent of temporal factors. In either case, the serial acquisition of the EMDEX II data does not appear to have injected bias into the results presented above. A previous article had compared the performance of a data logger (Muti-Wave System III, MWIII), which operates with a 1-s recording cycle to the EMDEX Lite, with a 4-s cycle (the EMDEX Lite is a more compact form of the EMDEX, and has been used in numerous exposure and characterization studies).[9] Although the EMDEX Lite did not perform as well as the MWIII recording maxima, those results cannot be extrapolated to the current study, which relied on a 1.5 s cycle.

Thus, the data collected in this characterization indicate that all fields across the spectrum comply with established exposure limits for "controlled" environments (IEEE) or occupational groups (ICNIRP). Although directly at the surface of selected transformer and inverter units (where members of the public are not expected to be present), magnetic field levels approximated ICNIRP general public exposure limits, they dropped well below those limits within a distance of less than 30 cm. Thus, the investigators of this article do not consider exceedance under those circumstances as a realistically plausible scenario for public exposure. In the frequency range regulated by the FCC, the fields were negligible relative to FCC's exposure limits.

This is the first study we know of to evaluate commercial photovoltaic facilities. In that light, the investigators were operating in a "research and discovery" context, and with limited time and access to the facilities, used the approaches based on their extensive experience most likely to return practical results in terms of alerting the site operator to the presence of hotspots or other field conditions that would be appropriate to communicate to the site's employees. Relative to limits for occupational groups (ICNIRP) and/or controlled environments (IEEE), there were no field levels measured that would be considered hotspots requiring follow-up at this point. However, were follow-up warranted and agency or company reporting required, we recommend that any formal assessment adhere to measurement guidelines such as those published by IEEE in Std 95.3.1-2010.[10] In addition to recommended measurement practices, this standard provides a quantitative methodology for assessing compliance, and such a need could arise in association with higher powered facilities that remain uncharacterized.

FUNDING

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Attachment B, Item 14, Holcomb handout

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MEASUREMENT AND ANALYSIS OF ELECTRIC AND MAGNETIC FIELD STRENGTH IN GRID-TIED PHOTOVOLTAIC POWER SYSTEM COMPONENTS

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In this study, electric field and magnetic field strengths at 50 Hz are measured in a solar power plant located far from residential areas, and the measurement results near various sources of the electric and magnetic fields in the power plant are presented. Although the measured values for the electric field caused by the solar panel range between 0.07 and 1.33 V/m, the measured values for the magnetic field by the solar panel range between 0.037 and 0.19 μT. In front of the inverter, the measured value of the electric field reaches 0.7 V/m, whereas the measured value of the magnetic field reaches 2.2 μT. The results are presented and evaluated in light of the exposure limits to electromagnetic fields published by international organisations.

INTRODUCTION

Electrical energy, one of the essential elements that societies need, is divided into two classes in terms of resources. These are renewable, consisting of sources such as solar, wind, hydraulic, geothermal, biomass and wave energy, and non-renewable (consumable) energy, consisting of sources such as nuclear, oil, natural gas and coal. Since existing consumable energy resources are widely proven to cause climate change and are costly and unsustainable, countries now tend towards alternative energy resources; this increases the interest in renewable energy sources.

Sunshine duration and the wavelength of solar radiation are effective factors for energy production in solar power plants. As such, Turkey has significant potential for generating solar power, thanks to its geographic location.

With increasing solar power plant installations, the adverse effects resulting from these systems have recently become the focus of research; studies related to this topic have begun to accelerate. In-plant inverters that convert direct current (DC) to alternating current (AC) create disturbances due to their high-frequency switching actions[(1)]. These disturbances arise from the inverter and are transmitted to the solar modules through power cables. Then, electric and magnetic fields radiate from the solar panels, which act as an antenna[(1, 2)]. For this reason, radiated electric field levels have been measured around power plant components. The electric and magnetic fields of solar power plants in the extremely low-frequency (ELF) range must fall under the international exposure guidelines for electromagnetic field levels. This is to ensure that the devices in the electromagnetic environment and those using the electrical energy may be run without being affected by their emissions.

Various studies are investigating the effects of magnetic field on human health for the ELF range. Ozen conducted magnetic field strength measurements near a 380/154 kV substation and near to power transmission lines (380 and 154 kV) to examine the occupational exposure of employees in substations and to examine the induced electric field and current densities for those who are exposed to a magnetic field radiated from a 380/154 kV substation. These measurements were carried out under the 380 kV busbar, in the control room and in the measurement room, and under the 154 kV busbar, in the 154/31.5 kV control room and near transformers[(3)]. In another study, magnetic field measurements were conducted at 154/31.5 kV transformer centres in Antalya with 12 participants to evaluate occupational exposure. Measured values varied between 0.3 and 1 μT on the operator tables and between 23 and 70 μT on the switch panel. In the circuit breaker area, the outdoor magnetic field measurement was up to 62 mT according to operator heights[(4)].

Loschi *et al.*[(5)] studied the effect of conducted and radiated emissions on electromagnetic compatibility at the DC and AC lines in photovoltaic system components. They suggested that current-carrying cables behave as unwanted active antennas in the radiofrequency range. Wu *et al.*[(2)] investigated the radiation mechanism caused by common-mode disturbance emitted from the DC side of a photovoltaic system between 150 and 30 MHz frequency range. Safigianni *et al.*[(6)] investigated electric and magnetic

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Table 1. Technical parameters of the solar modules.

Parameter	Value
P_m (maximum power, W)	250 W
Power tolerance (%)	0 ± 3
V_{mpp} (voltage at maximum power, V)	30.6 V
I_{mpp} (current at maximum power, A)	8.17 A
V_{oc} (V)—open circuit voltage	36.3 V
I_{sc} (A)—short circuit current	8.71 A
Maximum system voltage (V)	1000 V
Module size	$1640 \times 990 \times 40\ mm^3$

Table 2. Technical parameters of the inverters.

Property	Parameter name	Value
DC Input	V_{dc} max	1000 V
	V_{dc} MPP	200–950 V
	V_{dc}, full power	500–800 V
	I_{dc} max	2×32 A
	I_{sc} max	2×40 A
AC Output	V_{acr}	400 V/3Φ
	f	50 Hz
	P_{acr} ($\cos\phi = 1$)	27.6 kW @ 45°C
	P_{acr} ($\cos\phi \pm 0.9$)	27.6 kW @ 45°C
	I_{ac} max	45 A

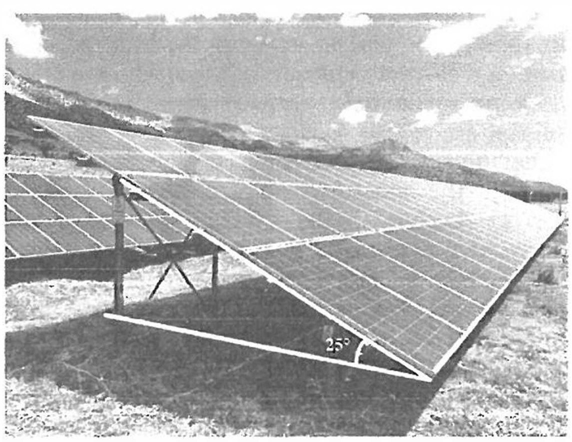

Figure 1: Placement angle of the solar panels.

fields in a high-voltage centre consisting of 400/150 and 150/20 kV transformer substations. Electric field values in some locations exceeded the reference level for acceptable occupational exposure. İl *et al.*[7] analysed the ELF magnetic fields that occur around underground energy cables using measurement and computational methods, and investigated the control of 50 Hz magnetic fields by means of a shielding technique. In low-voltage and high-voltage cable ducts, field measurements were performed every 10 cm at vertical distances. Furthermore, measurement-based studies were carried out in different locations and different seasons for electric and magnetic field analyses in rooftop photovoltaic systems[8, 9]. McCallum *et al.*[10] took magnetic field measurements from different points ranging between 0 and 500 m to evaluate the magnetic field caused by a wind turbine.

To avoid adverse health effects of ELF magnetic fields, the American Conference of Governmental Industrial Hygienists (ACGIH) published a magnetic flux density exposure limit of 1.2 mT for the whole body at the frequency of 50 Hz[11, 12]. The Institute of Electrical and Electronics Engineers (IEEE) and the International Commission on Non-Ionising Radiation Protection (ICNIRP) have established the limits for ELF magnetic flux density to be 904 and 200 μT for the general public, whereas 2710 and 1000 μT are the ceilings for occupational exposure, respectively[13, 14].

Although there are studies in the literature involving both electric and magnetic field analyses in facilities where electricity is produced by alternative technologies, no detailed studies are available for solar power plants. Therefore, in this study, real-time electric and magnetic field measurements are carried out around the solar panels, inverters and transformer station of a solar power plant. The operating frequency is 50 Hz, the rated primary voltage is 31.5 kV, the rated secondary voltage is 0.4 kV and the rated power of the hermetically sealed step-up transformer is 1000 kVA. In the transformer station, magnetic field measurements are carried out. Both the electric and the magnetic field intensities are measured in front of the photovoltaic panels and at the inverter's side. According to the measurements, the compliance of the observed fields with international standards is discussed. The remainder of the paper will be structured as follows. First, the materials and methods, along with basic information about the power plant, are presented. The next section provides the detailed measurements that were recorded of the electric and magnetic fields. The specifications of the instruments used to record the measurements are indicated. Finally, the results of the research are given, along with a discussion.

MATERIALS AND METHODS

A solar cell has a semiconductor material structure and produces electrical energy from photon energy. Solar power plants are made up of solar cells that can be installed in two distinct ways, as on-grid or off-grid. In the on-grid system, energy produced by the solar panels is supplied directly to the network, whereas in the off-grid system, the generated energy is stored in batteries.

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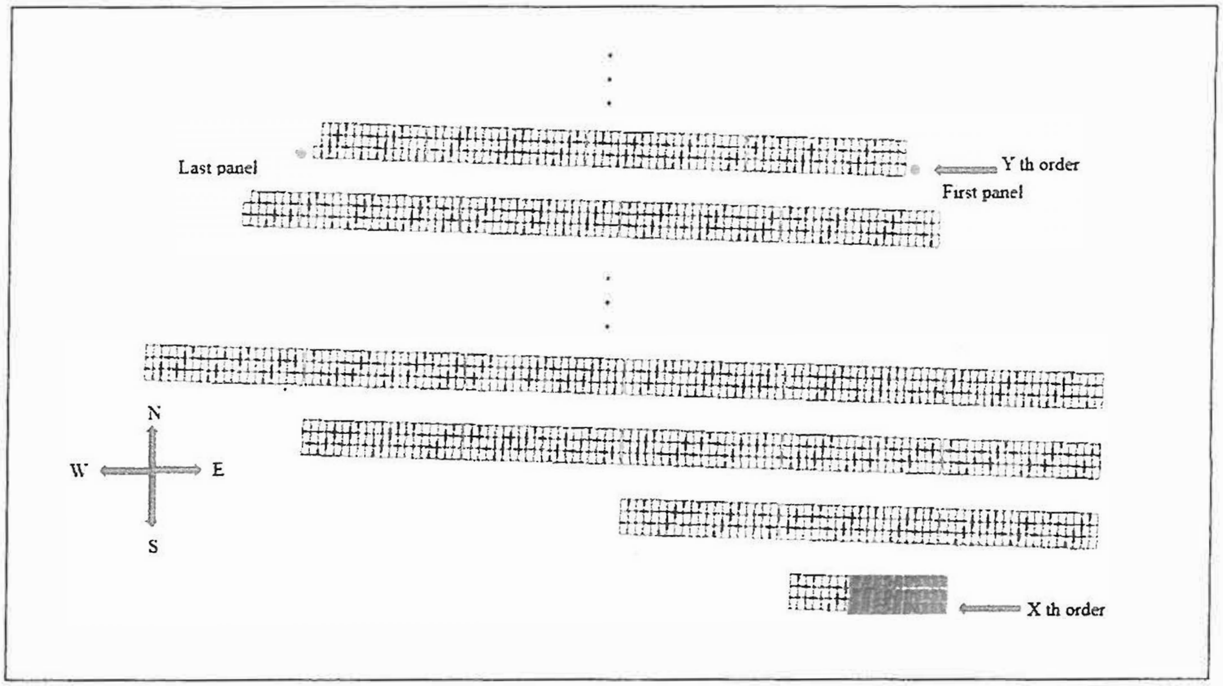

Figure 2: Solar power plant's outline.

Table 3. Measured magnetic field values for the corners of the transformer station (μT)

Measurement height (m)	SW corner	SE corner	NW corner	NE corner
0	0.55	1.775	3.79	14.25
0.5	0.51	0.95	5.34	8.7
1	0.33	0.73	6.25	5.25
1.5	0.37	0.46	7.95	3.62

SW, southwest; SE, southeast; NW, northwest; NE, northeast.

In this study, the solar power plant where measurements were carried out is located in Elmali, Antalya. The solar power plant has 800kWp (kilowatt-peak) of installed power, and its solar panels are produced according to the international standard of International Electrotechnical Comission (IEC) 61215 (Crystalline Silicon Terrestrial Photovoltaic Modules-Design Evaluation and Type Acceptance), which is valid for photovoltaic panels. At the plant, there are 3200 polycrystalline panels with 250 W output power. Each panel is made up of 60 series connected polycrystalline solar cells of $156 \times 156\ mm^2$. The panels are placed on the support structure at an angle with the ground of 25°. The panel placement is shown in Figure 1. The technical specifications of the solar modules are shown in Table 1.

The plant also has 27 inverters, each of which has 27.6 kW of power. The technical specifications of the inverters are shown in Table 2.

Furthermore, the electrical powers of the four low voltage electric panels at the facility are 240, 270, 180 and 110 kW, respectively.

The energy generated in the plant is transmitted to an interconnected system after it is adapted to the national network's electricity values via a step-up transformer located in a fabricated kiosk ($7.30 \times 2.50\ m^2$ size).

The energy generated at the plant and that consumed at the same facility are recorded by an up-down counter.

MEASUREMENTS OF ELECTRIC AND MAGNETIC FIELD STRENGTH

Measurements were carried out under load at a solar power plant site. The electric field strengths were measured using an EMR-300 with an appropriate probe (Narda, Germany). The magnetic field strengths were measured using a Hioki 3470 magnetic

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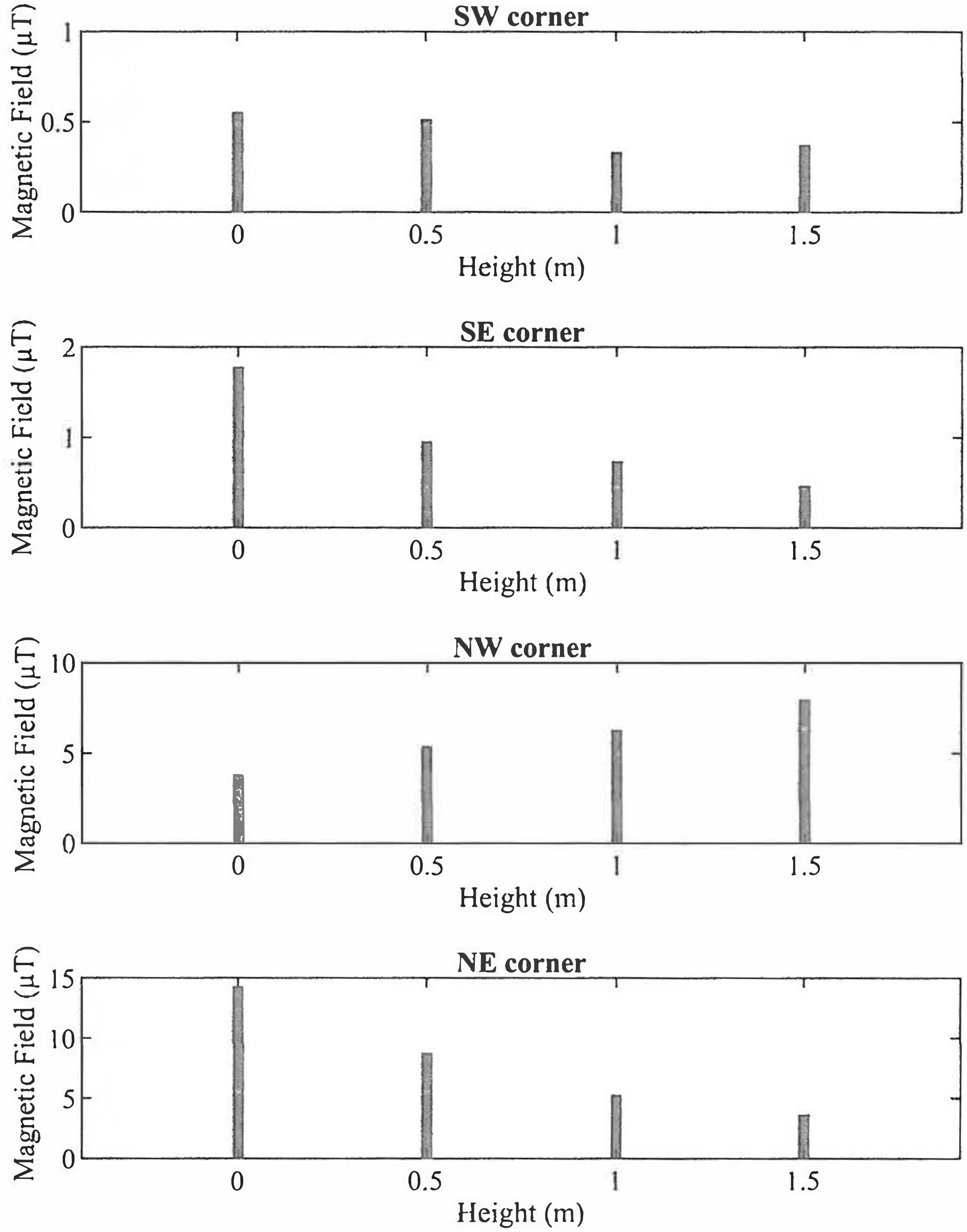

Figure 3: Magnetic field measurements for transformer's corners.

field HiTESTER (Hioki EE Corp., Japan) with an appropriate probe.

Figure 2 shows the solar power plant's outline and identifies where the electric and magnetic field measurements were carried out at the operating frequency of 50 Hz. The electric and magnetic fields were measured on 25 August 2019, under partly sunny and partly cloudy weather conditions. Since this study aims to investigate the exposure of electromagnetic fields on human health and effects to the environment, measurements were performed especially in areas where employees may be exposed.

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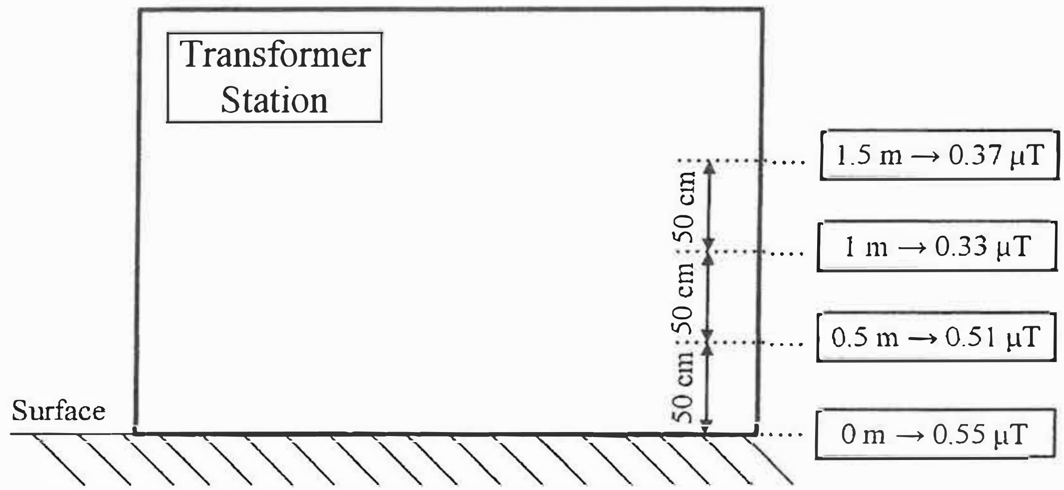

Figure 4: The magnetic field measurement points for the southeast corner of the transformer cell.

Measurements at power transformer's corner

The magnetic fields were measured at the southwest, southeast (SE), northwest and northeast corners of the transformer station. At each corner of the transformer station, magnetic field measurements were performed at four different points at a distance of 30 cm horizontally. The vertical distances of these points were 0 m (floor), 0.5 m (knee level), 1 m (waist level) and 1.5 m (shoulder level), according to the operator height from the ground. The measured magnetic field intensities at each evaluation height on the transformer corners are given in Table 3 and graphics are given in Figure 3. The measurements were carried out by recording the average magnetic field values. As shown in Table 3, while the magnetic field intensity at ground level near the transformer reached a maximum of 14.25 μT, the maximum value at 1.5 m height was measured as just 7.95 μT.

The magnetic field measured values and their positions for the SE corner of the transformer station are shown in Figure 4.

Measurements on photovoltaic panels

Measurements were carried out at one in every five panels, including the first and last panels, in the *X*th and the *Y*th row, as shown in Figure 2. The electric and magnetic field changes according to the panels in the *X*th row are given in Figures 5 and 6, respectively.

As can be seen from the measurement results given in Figures 5 and 6, the electric field intensity emitted from the panels varied between 0.18 and 0.34 V/m, whereas the magnetic field intensity emitted from the panels varied between 0.18 and 0.19 μT.

The electric field and magnetic field changes of the *Y*th row, according to the panels, are indicated in Figures 7 and 8, respectively.

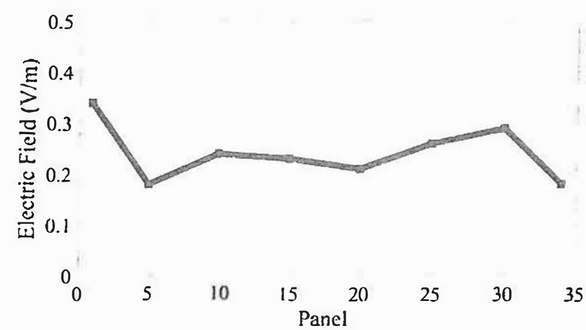

Figure 5: Electric field strength measurement results in the *X*th order.

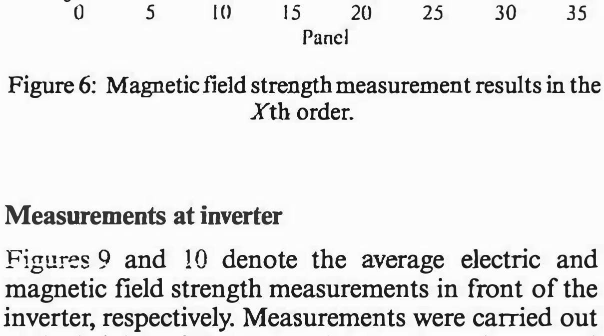

Figure 6: Magnetic field strength measurement results in the *X*th order.

Measurements at inverter

Figures 9 and 10 denote the average electric and magnetic field strength measurements in front of the inverter, respectively. Measurements were carried out at the heights of 0, 0.5, 1 and 1.5 m from the ground level.

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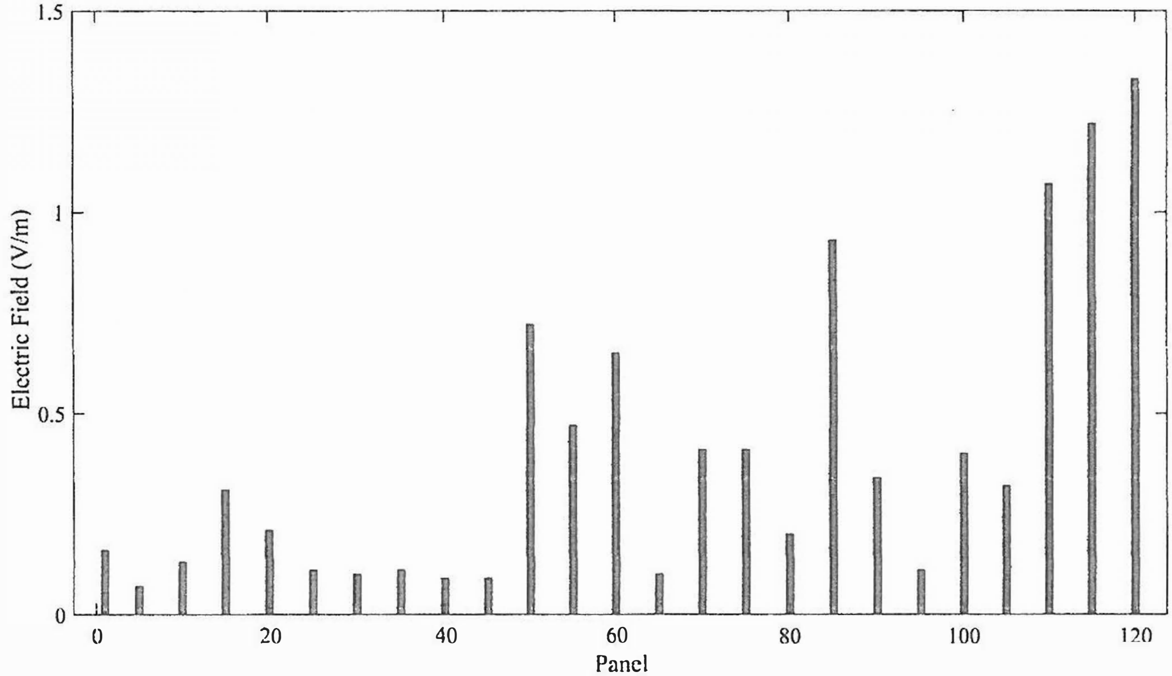

Figure 7: Electric field strength measurement results in the Yth order.

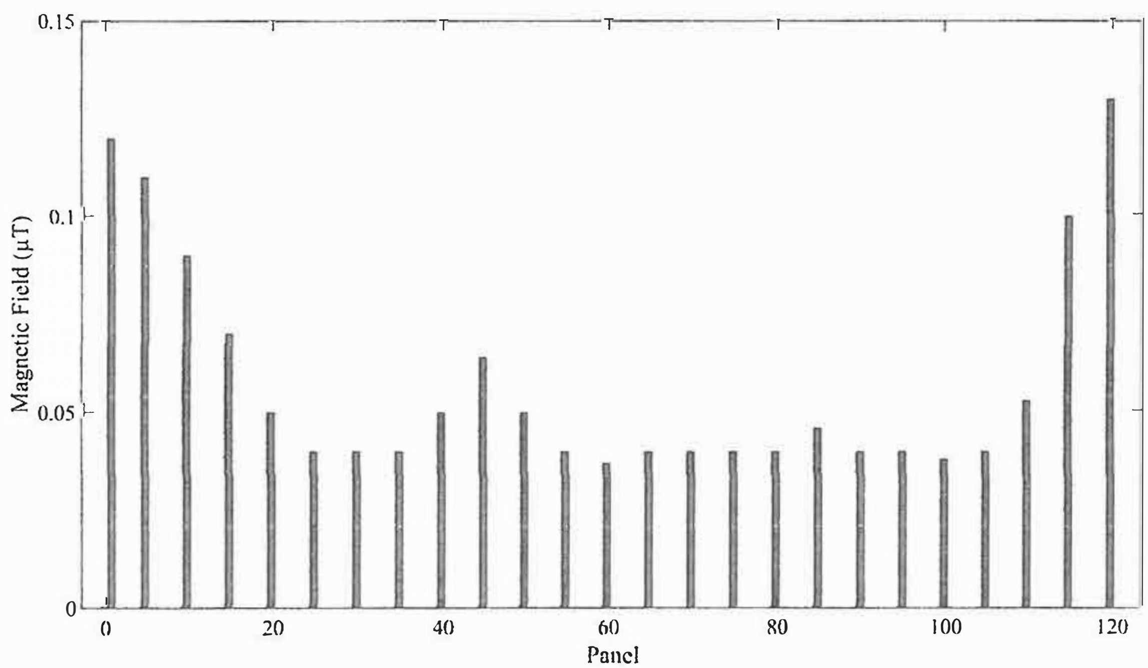

Figure 8: Magnetic field strength measurement results in the Yth order.

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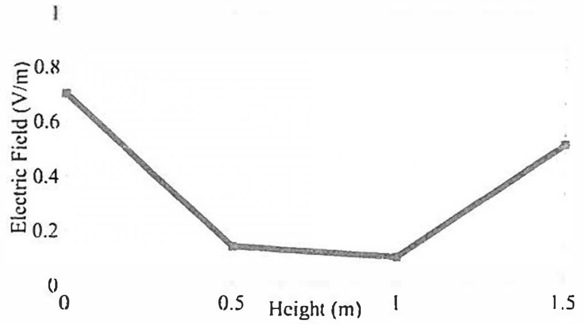

Figure 9: Electric field strength measurements for the inverter.

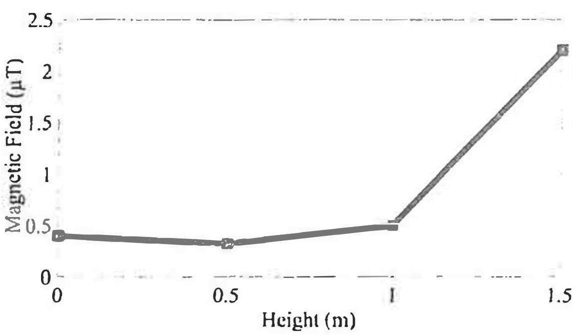

Figure 10: Magnetic field strength measurements for the inverter.

As can be seen from the measured values given in Figure 10, the magnetic field intensity varied between 0.32 and 2.2 µT.

DISCUSSION AND CONCLUSION

In this study, real-time electric and magnetic field analyses were performed upon the components of a grid-connected solar power plant system.

Magnetic field levels were measured both at the solar power plant site and around the transformer. As can be seen in Table 3, it was observed that the magnetic field measurement values varied between 0.33 and 14.25 µT in the transformer station. For solar panels in the *X*th row, the magnetic field ranged between 0.18 and 0.19 µT, as given in Figure 2, whereas in the *Y*th row, the magnetic field reached 0.12 µT. In front of the inverter, the magnetic field values varied between 0.32 and 2.2 µT according to the height from the ground level, as shown in Figure 10.

To evaluate the fields from other possible sources, such as switching antennas, additional measurements of electric field were performed in the environment. Electric fields resulting from the *X*th row of panels varied between 0.18 and 0.34 V/m, whereas electric fields resulting from panels in the *Y*th row vary between 0.07 and 1.33 V/m. In front of the inverter, electric field values varied between 0.1 and 0.7 V/m according to the height from the ground level, as shown in Figure 9. Generally, it was observed that the measured results were consistent with each other and that the values may have varied depending on the changing weather conditions (sunny, cloudy, shady, etc.) during the measurement period.

Overall, it was observed that the electric and magnetic field levels were far below the occupational exposure limits of ICNIRP and IEEE in the places where employees may be exposed inside the plant. Furthermore, the obtained values complied with the ACGIH limits for ELF magnetic field exposure. This study has presented results in terms of the exposure to electric and magnetic fields of those working in a photovoltaic plant.

In the future, the electromagnetic field levels around the energy transmission lines passing through residential areas connected to the photovoltaic plant need to be investigated, and the results in terms of general public exposure need to be evaluated. To do so, the electric and magnetic fields resulting from photovoltaic panels in residential areas could be analysed with support from simulations. In addition to this, the interference effect of the electromagnetic field caused by the switching and the antenna effect should be examined in future research. In this way, the levels of electric and magnetic fields from solar power systems for both workers and the general public may be assessed in detail.

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