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Research & Innovation Action

December 2021

Production of a feasibility study as deliverable of task 16.2

Version N°1

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This project has received funding from the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement 963530.

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Document information

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Abbreviations and Acronyms

Acronym	Description
WP	Work Package
EPAC	Ecole Polytechnique d'Abomey-Calavi
SBEE	Société Béninoise d'Energie Electrique

Summary

Within the framework of the LEOPARD Project, it is planned to install a mini solar power plant on one of the electrical outlets of the Songhaï site in Benin. For a better appreciation of the energy needs of the part of the center to be supplied, a team of the project installed on 09/11/2021, an analyzer of the electrical grid on the outlet serving the beneficiary section (the village). The data was recorded from 11 to 24 November 2021 (14 days). From the analysis of the data, we can deduct the following:

- the maximum value of the absorbed power is 32,14 kW ;
- We count the power peaks in 04 different time ranges: (1) 2 a.m. to 3 a.m.; (2) 6 a.m. to 8 a.m.; (3) 1 p.m. to 3 p.m.; (4) 6 p.m. to 10 p.m.
- On all weekend days, there is no regular decrease in consumption;
- The site's electrical system resumes immediately after power outages without a particular absorbed power;
- Considering 6 a.m. to 6 p.m. as the daytime operating range, the daytime share of energy consumed varies from 45% to 51% for the 14 collection days;
- The highest daily consumption is recorded on Saturday, November 20, 2021. It is 290,29 kWh/day.

Keywords

Electrical grid Analyser ;solar minigrids ; Songhaï ; Leopard Project

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1. Context

The Songhaï center is supplied with electricity from the national electrical grid via a 250 kVA subscription with SBEE. In addition to this main source, the center has two emergency generators:

- A 150 kVA Power generator unit, which is used during off-peak hours, weekends and holidays;
- A second 250 kVA Power generator unit.

Figure N°1 shows the different power sources on the site.

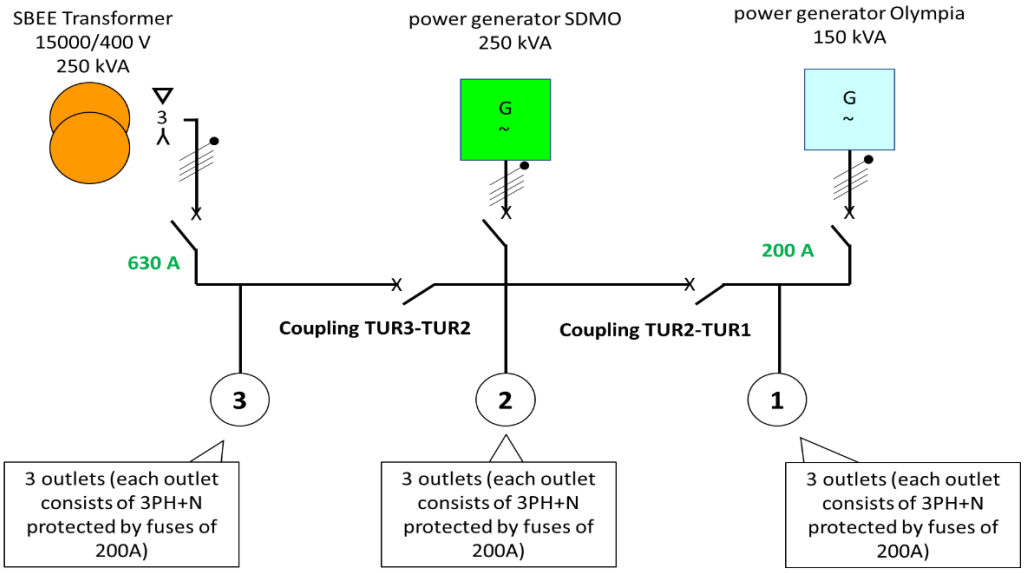

Figure 1 : Energy source available on the site of the Songhaï.

The LEOPARD Project plans to install a mini power plant on only one of the outlets in point 3 of Figure N°1. Figure N°2 shows the loads served by the electrical feeder selected for the "village" of the LEOPARD project.

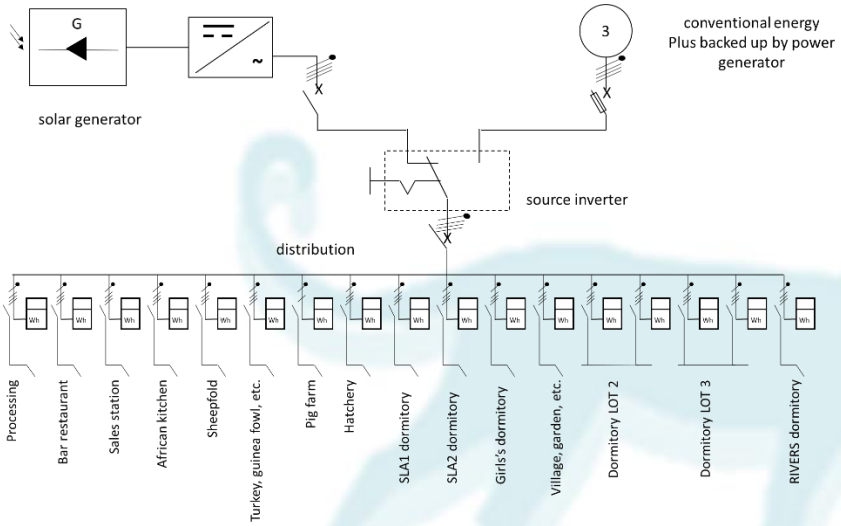

Figure 2 : Electrical plan of the target grid

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The main characteristics of the loads to be supplied are presented in the appendices of this document.

For a better appreciation of the energy needs of the part of the center to be supplied, a project team installed on 09/11/2021, a electrical grid analyzer on the electrical feeder serving the beneficiary section (the village).

2. Objectives

The expected duration of the registration is two weeks. The main objectives are:

- Recording of the daily load profile during working days and holidays;
- Identification of peak power demand hours;
- Determining the peak power demand.

3. Presentation of the electrical grid analyzer

The analyzer used is the C.A 8335 of the manufacturer CHAUVIN ARNOUX. The table N°1 presents the parameters that can be recorded by the analyzer.

Table 1: Parameters that can be recorded by the analyzer.

Unit	Description
Ums	RMS compound voltage
Vms	Simple efficient voltage
Arms	Effective current
Uthd	Total harmonic distortion of the compound voltage (THD-F)
Vthd	Total harmonic distortion of the simple voltage (THD-F)
Athd	Total harmonic distortion of the current (THD-F)
Ucf	Crest factor of the compound voltage
Vcf	Crest factor of the simple voltage
Acf	Current crest factor
W	Active power
VAR	Reactive power
VA	Apparent power
PF	Power factor
Vunb	Simple voltage imbalance
Aunb	Current imbalance
Hz	Electrical grid frequency
PST	Short term flicker
KF	K Factor

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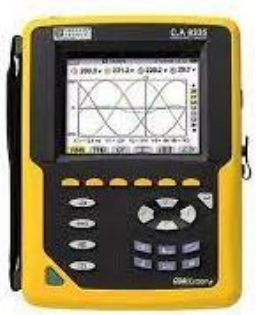
Table N°2 presents the components of the electrical grid analyzer.

Table 2: the various components of the equipment

Material	Role	Picture
ANALYZER	Allows to observe in real time the recorded information	
USB communication cable Computer-Monitor type A-B	Allows access from the POWER HARMONICS ANALYZER software to data stored on the monitor	
04 multi-calibre current clamps: 1 - 10 - 200A	Allows to collect the values of the intensity of the current (to hang on the cable)	
05 measuring leads + crocodile clips	Allows to collect the values of the electrical grid voltage (to be connected to a non isolated place of the circuit)	
01 power adapter	Allows the electrical grid analyzer to be powered from the mains	

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4. The different stages of equipment installation and data recording

The equipment electrical data recording phase is already operational on the site.

It should be noted that the team has a second analyzer that could be installed at other points of use in the identified area, but some constraints in the field did not allow for its installation. However, the team found that the information that will be collected will not be more useful unless a device is installed at each of the 15 points of use to allow for simultaneous measurements to be taken and to compare the sum of the results with those collected on the main analyzer. In conclusion only one electrical grid analyser was installed.

5. The different stages of data extraction

The data extraction is made following the operating mode of the device

6. Experimental protocol

- The duration of the recording is 14 days including two weekends with a recording step of 01 minute.
- A series of power outages and restarts are planned for at least two different peak hours.
- The peak time slots are identified as following (information received from Songhaï officials in charge of managing the electrical grid); they are 7am to 1pm and 3pm to 7pm.
- The days concerned by the simulated production outages will be noted and considered for the treatment. The series of power outages and restarts during peak periods will allow a better assessment of the starting power demand during periods of high demand.
- An electrical technician is in charge of the daily monitoring of the installation. Every morning, he sends photos of the recorder on a daily basis. This ensures the continuity of the recording;
- The EPAC team plan also to make unannounced visits for in-situ checks.

7. Brief overview of the installation phase

The device was installed in the technical room in accordance with the manufacturer's instructions. To ensure the continuity of the recording in case of prolonged cut of the conventional source (Beninese Company of Electric Energy "SBEE"), it was installed an inverter-charger of 1200 W with a battery of 150 Ah/12 V to reinforce the autonomy of the internal battery of the recorder.

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Galerie photos

Presentation of the analyzer 	**Installation of the Backup** 
Installation phase of the grid analyzer 	

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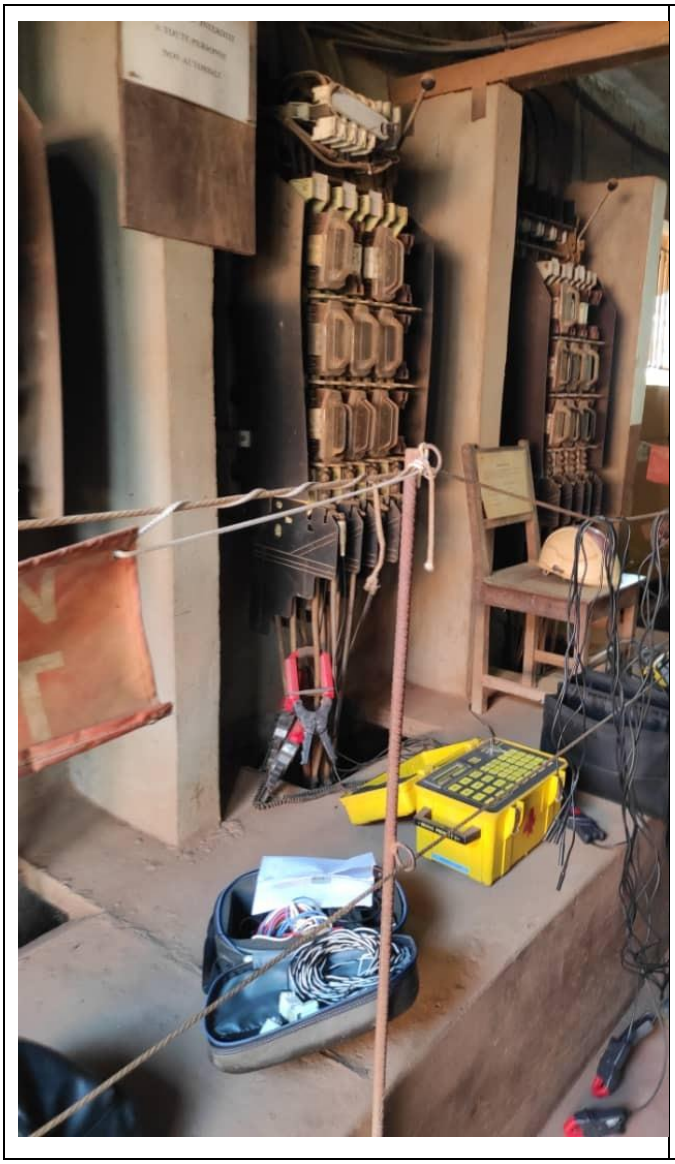

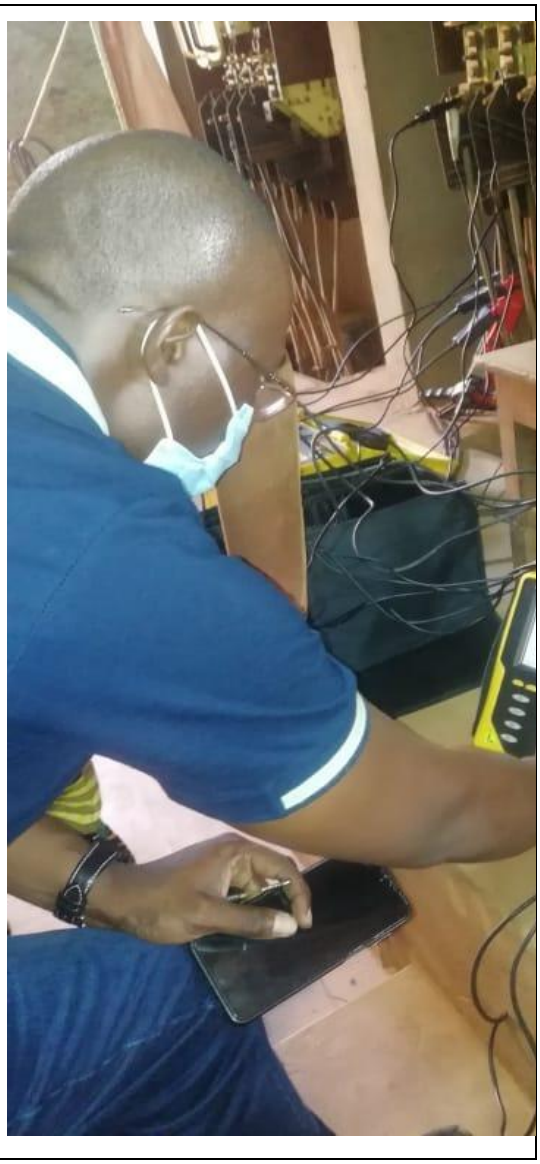

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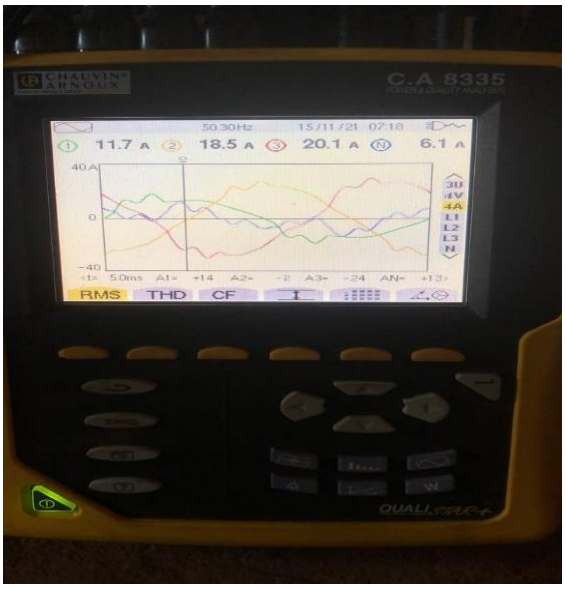
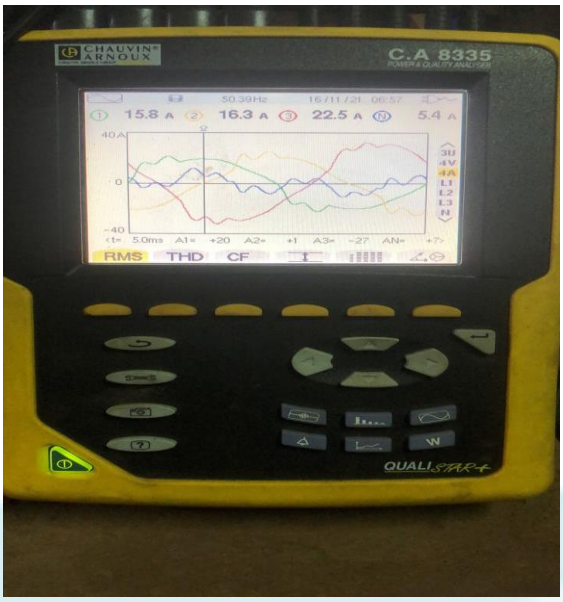
Some screenshots of the Analyzer; captures made by the technician of SONGHAI allowing the team, which is not on site, to ensure its operation

	
Monday November 15th at 7:22am	**Monday, November 15 at 4:39 pm at the Sector Break**
	
Monday, November 15 at 4:41 p.m. at the sector recovery	**Tuesday November 16th at 07h02**

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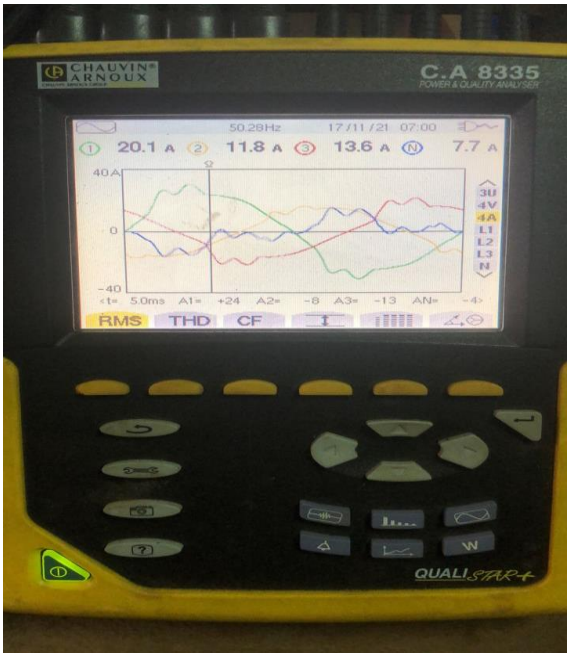
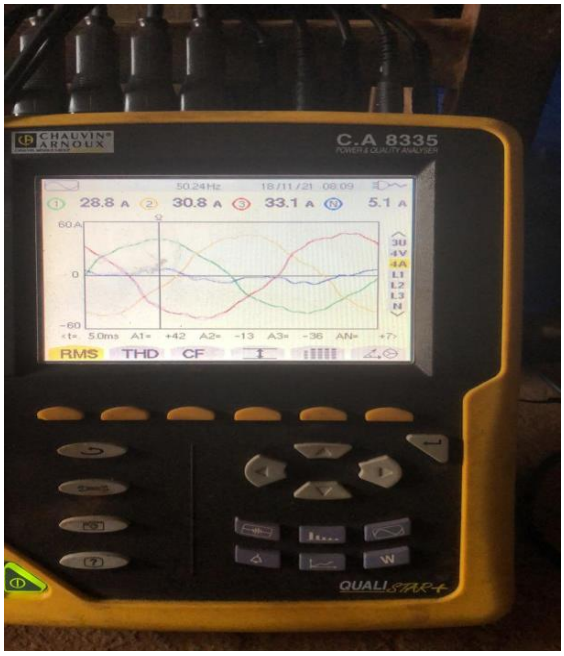
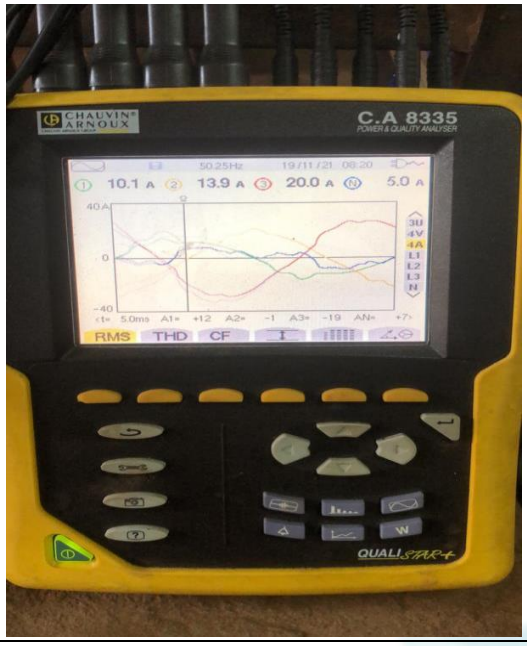
	
Wednesday, November 17 at 7:05 am	**Thursday November 18th at 8:14am**
	
Friday November 19th at 8:25 am	**Saturday November 20th at 11:28am**

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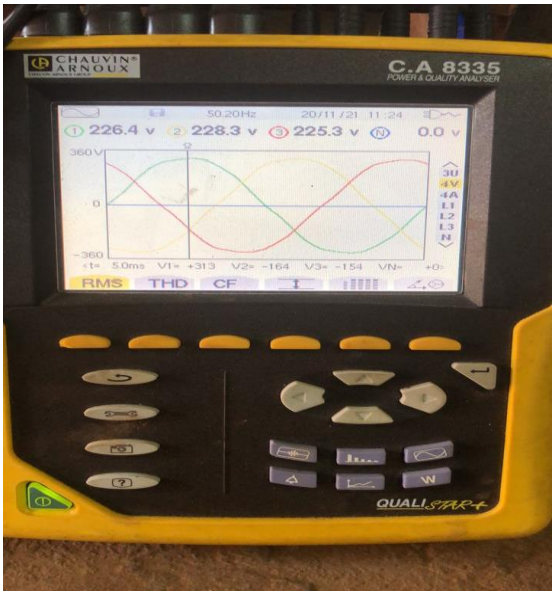	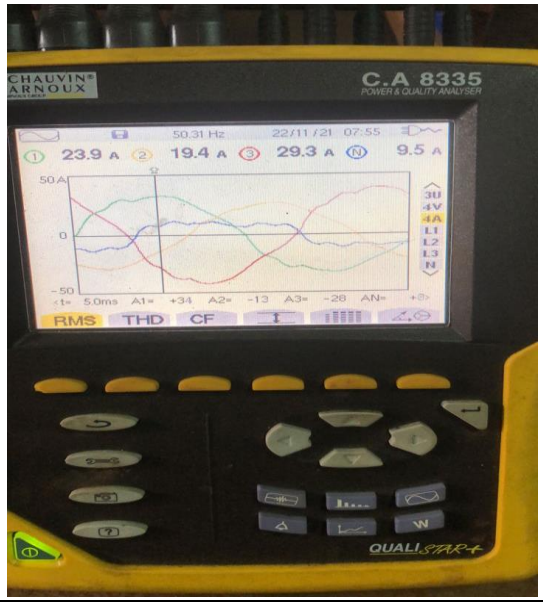
Saturday November 20th at 11:28am	**Monday November 22nd at 8:00 am**

8. Overview of data collected and analysis

8.1 Variation of phase-to-neutral RMS voltages

Figure 3 shows the RMS voltage variations at the three phases. These voltages vary between 205 V and 236 V.

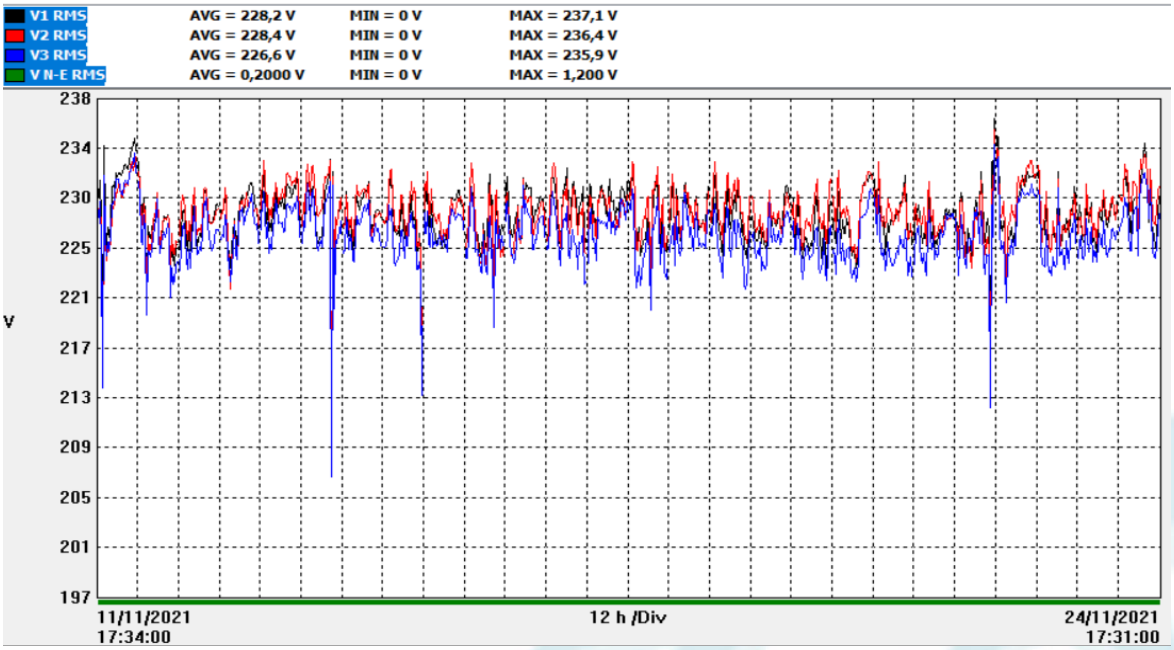

Figure 3: Variation of the RMS voltages on the three phases

This record indicates a certain stability of the grid voltage on the site.

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8.2 Active power on the three phases

Figure 4 shows the active power variations on each phase.

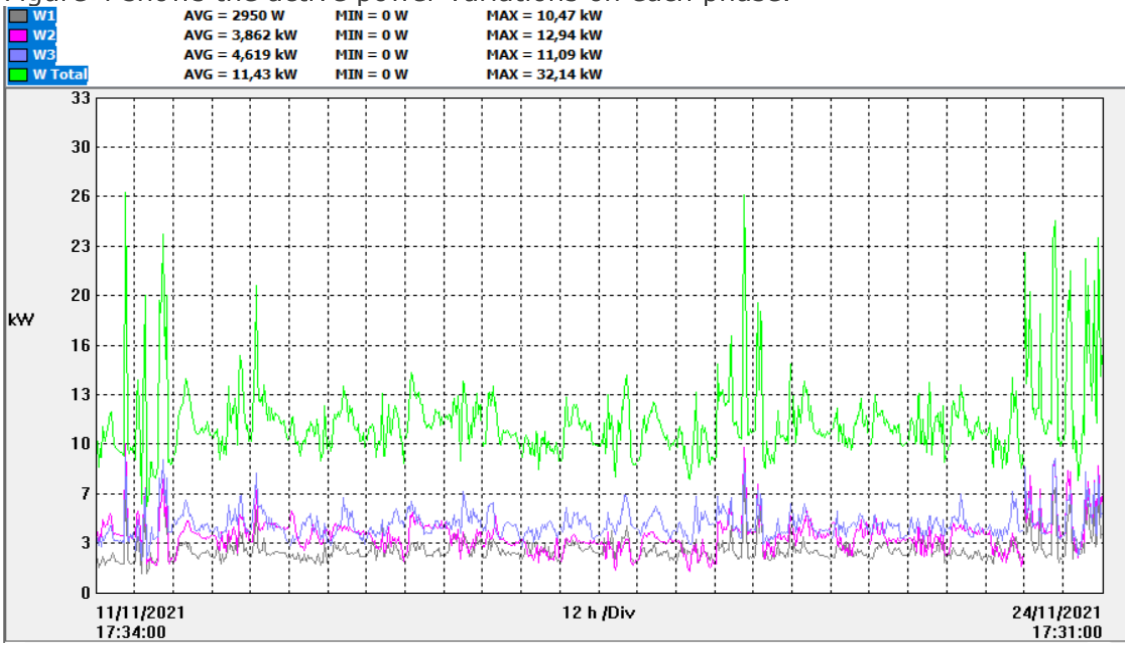

Figure 4 : Variation of the active powers on the three phases

The maximum power demand on the phases is 10.47 kW; 11.09 kW and 12.94 kW. The maximum value of the total active power is 32.14 kW.

8.3 Reactive power on the three phases

Figure 5 shows the reactive power variations on each phase.

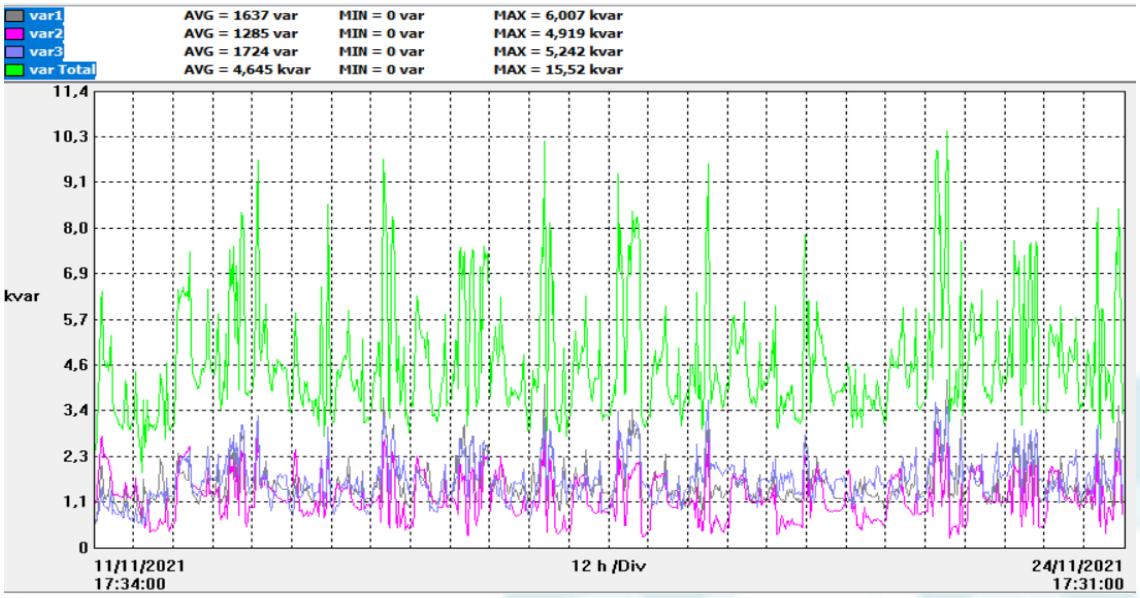

Figure 5 : Variation of the reactive powers on the three phases

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The reactive powers vary from 4.9 to 6 kVar on the phases. The maximum value of the total reactive power is 15.52 kVar.

8.4 Apparent power

Figure 6 shows the variations of the apparent power of the three-phase electrical grid.

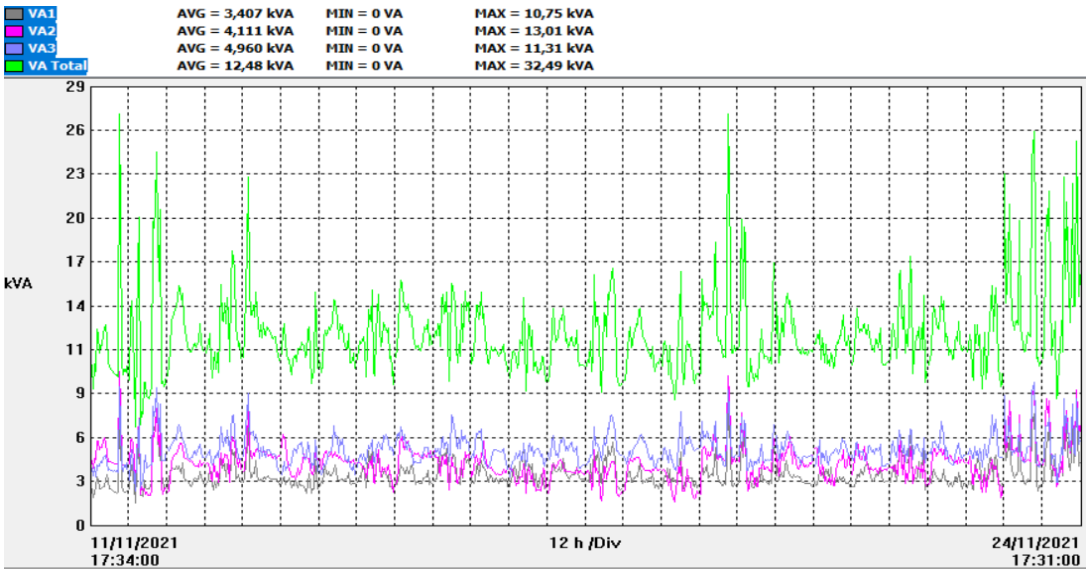

Figure 6 : Variation of the apparent powers of the three-phase electrical grid

The maximum apparent power per phase is 13.01 kVA. The maximum total apparent power is 32.49 kVA.

8.5 Power factor

Figure 7 shows the power factor variations on the three-phase electrical grid.

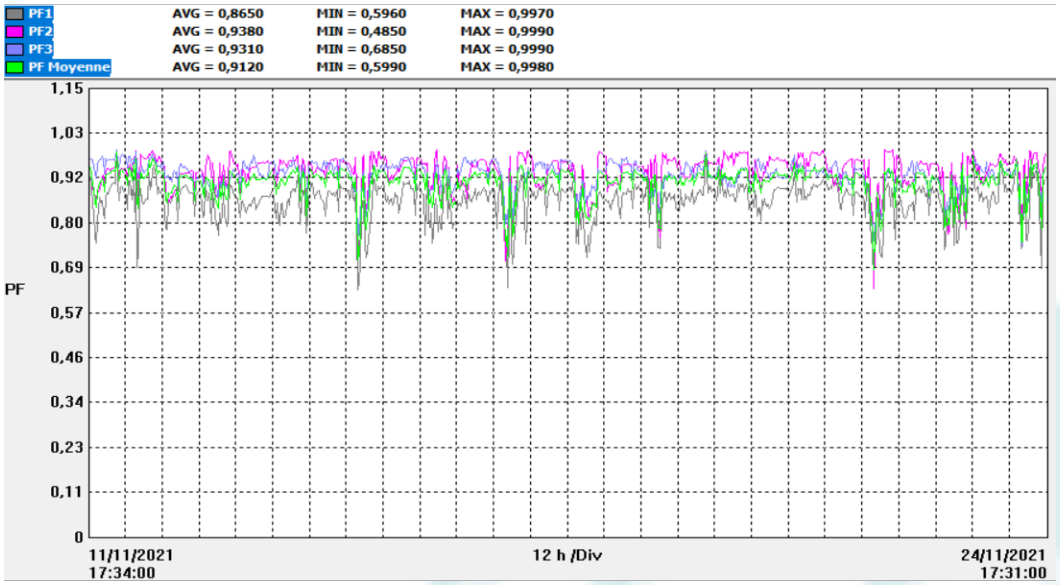

Figure 7 : Variation of power factors

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The power factor varies from 0.6 to 0.998. The average of 0.91 indicates a low presence of reactive equipment on the electrical grid to be supplied.

9. Daily variation of the main parameters

9.1 Daily variation of composite RMS voltages (Ph-Ph)

The figures**Erreur ! Source du renvoi introuvable.** ; 9 and 10 show the daily variations of the RMS voltages on the different phases of the electrical grid.

Figure 8 : Daily variation of RMS voltage on phase 1.

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RMS voltage on Phase 2

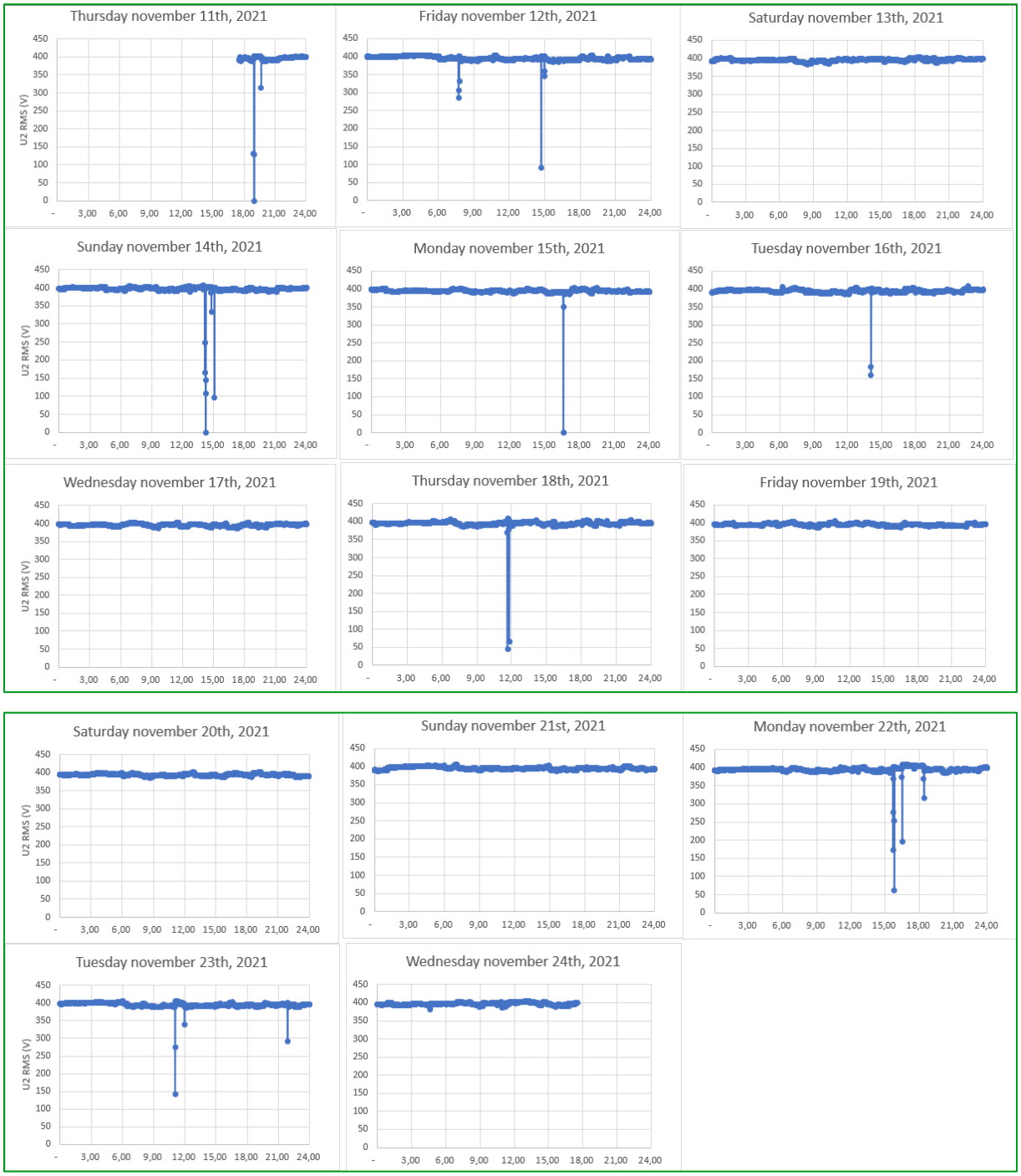

Figure 9 : Daily variation of RMS voltage on phase 2

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RMS voltage on Phase 3

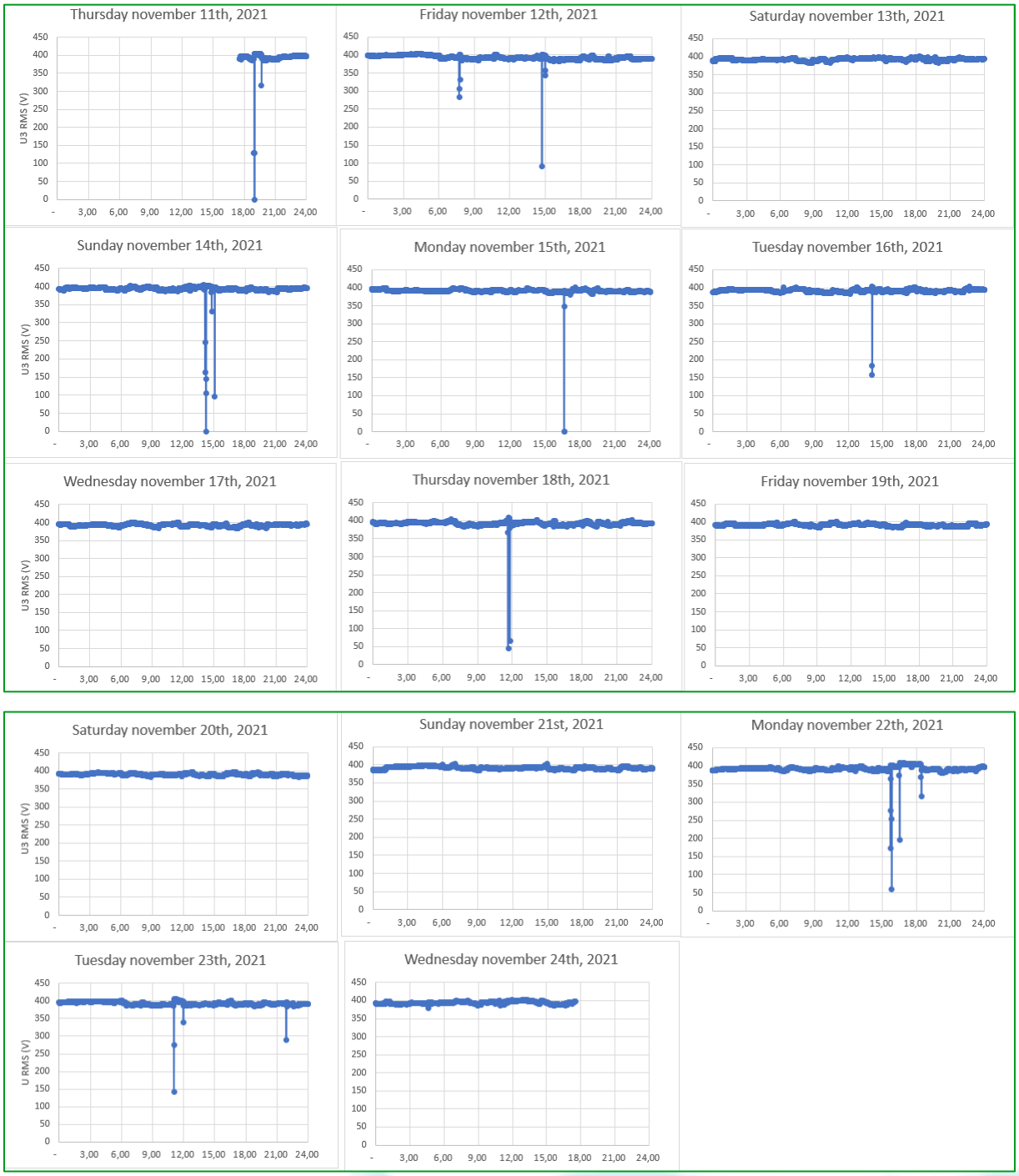

Figure 10 : Daily variation of RMS voltage on phase 3.

From the analysis of the previous graphs, we can see that there were significant drops in voltage on 12, 16, 18, 22 and 23 November. These drops are observed simultaneously on all three phases.

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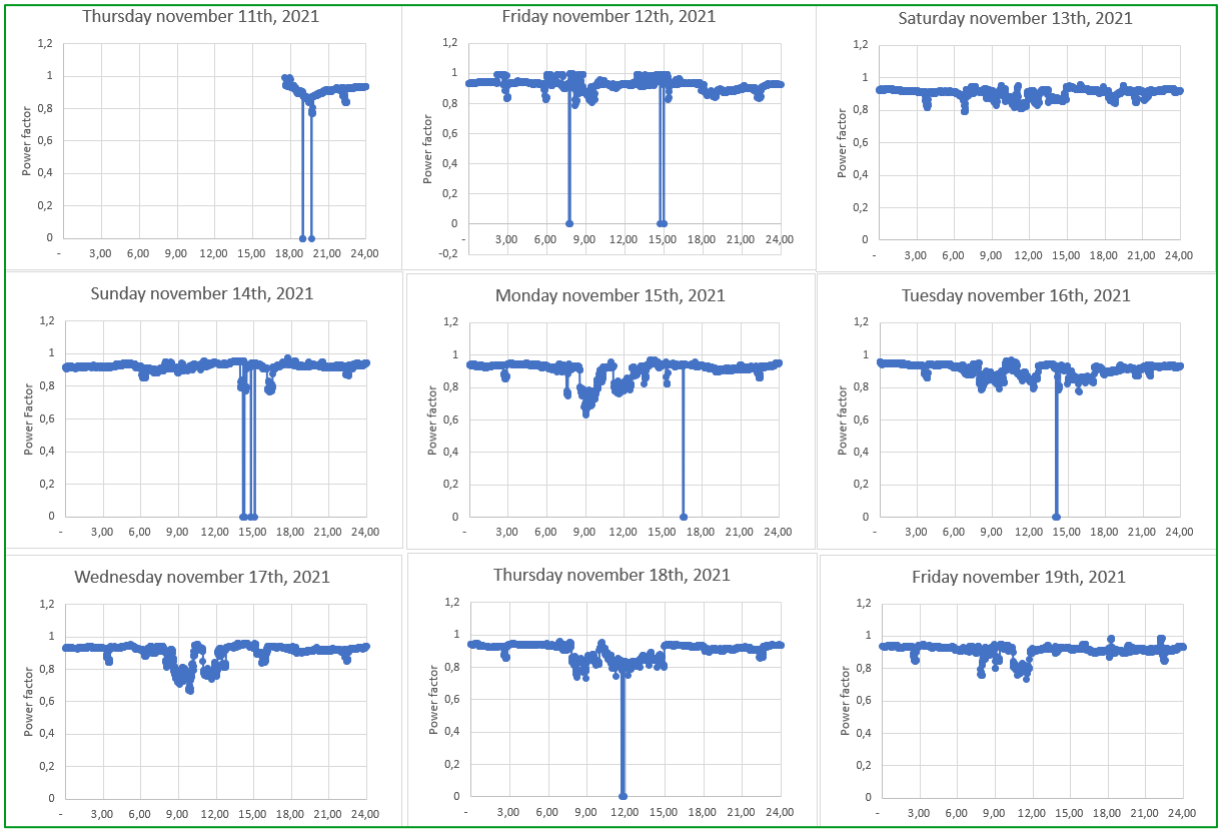
9.2 Daily variation of power factors

Figure 11 shows the daily variation of the average power factor values.



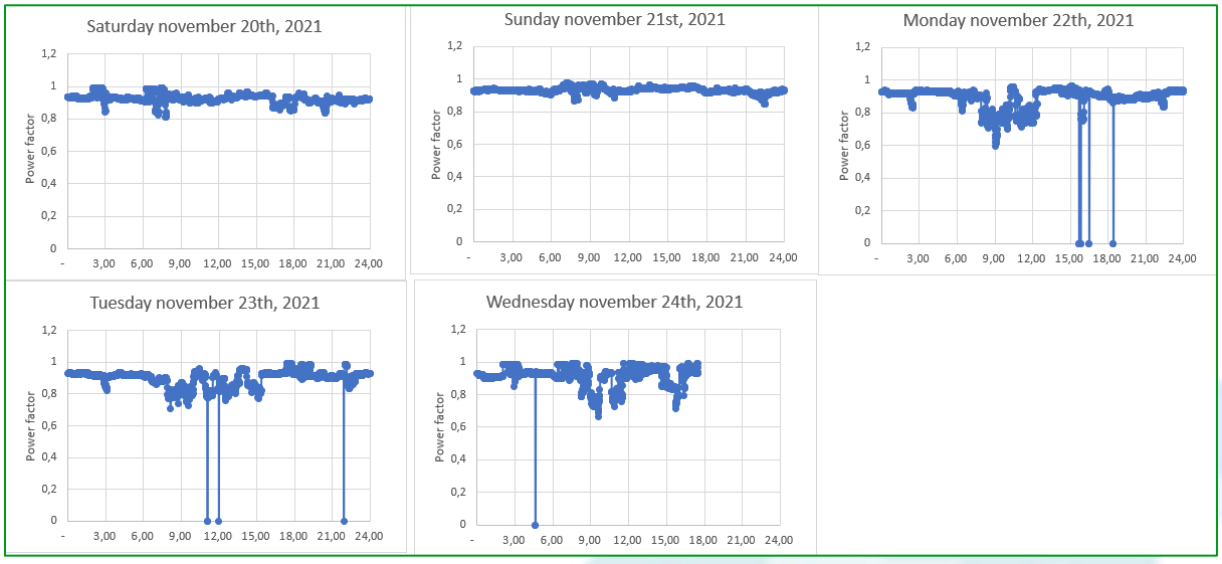


Figure 11 : Variation in total active power over the 14 days of data collection.

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9.3 Daily variation in total power demand

Figure 12 shows the daily variation of the total power measured by the grid analyzer.

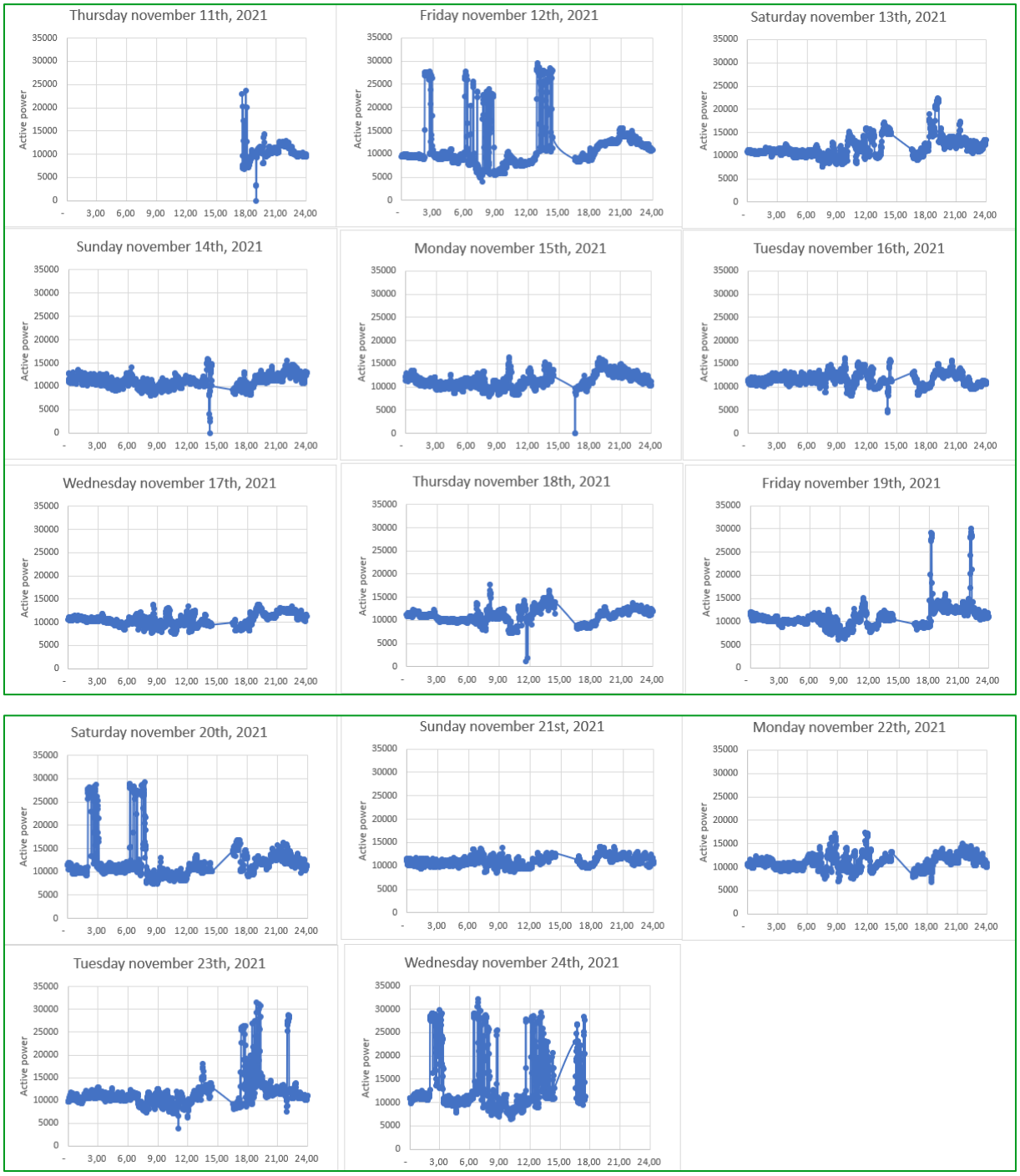

Figure 12 : Variation in total active power over the 14 days of data collection

This project has received funding from the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement 963530.

From the analysis of the previous graph, we can deduct the following:

- Over the 14 days of observation, the maximum value of the active power is 32.14 kW;
- The power peaks are recorded in 04 different time slots: (1) 2am to 3am; (2) 6am to 8am; (3) 1pm to 3pm; (4) 6pm to 10pm.
- No regular decrease in consumption is recorded the weekend days;
- By analyzing the recorded data, it is clear that there were three power outages, namely on Thursday 11 (around 7pm); Sunday 14 (around 2pm) and Monday 15 November (between 4pm and 5pm);
- The system resumes right after the outages without a particular call of power.
- Considering 6am to 6pm as the daytime operating range, the daytime share of energy consumed varies from 45% to 51% for the 14 collection days.

10. Update on daily consumption

Table 3 shows the average daily consumption over the observation period

Table 3 : daily consumption over the observation period

	Sum of kWh Phase 1	Sum of kWh Phase 2	Sum of kWh Phase 3	Sum of kWh Total
11/11/2021	14,33	28,15	24,34	66,83
12/11/2021	74,67	96,49	113,48	284,65
13/11/2021	69,62	97,46	116,25	283,33
14/11/2021	62,11	99,39	103,07	264,57
15/11/2021	68,34	92,85	109,98	271,17
16/11/2021	72,89	93,21	114,42	280,52
17/11/2021	68,47	74,17	105,79	248,43
18/11/2021	71,06	76,28	113,20	260,53
19/11/2021	66,36	79,33	112,04	257,73
20/11/2021	74,53	103,63	112,13	290,29
21/11/2021	66,95	92,50	106,46	265,91
22/11/2021	70,47	87,13	108,55	266,14
23/11/2021	72,07	92,72	110,41	275,20
24/11/2021	68,41	91,41	90,75	250,56

The highest consumption of 290,29 kWh/day, is recorded on Saturday, November 20, 2021.

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11. Appendices

THE POINT OF THE ELECTRICAL EQUIPMENT

- **Location: Processing**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
AIR BLOWER	4	220V	65W	TO BE USED DURING PRODUCTION
LAMP	6	220V	36W	
POWER SOCKET				
INCUBATOR	1	220V	2	TO BE USED DURING PRODUCTION
GAS OVEN	1	220V	2,5A	TO BE USED DURING PRODUCTION
ELECTRIC OVEN	1	380	20 A	TO BE USED DURING PRODUCTION
FREEZER	1	220V	180W	USED 24 HOURS A DAY
JUICE EXTRACTOR (GINGER, MANGO)	2	380v	3HP	SEASONAL USE
CORN MILL	1	380V	10HP	USED 3 TIMES A WEEK
AIR CONDITIONER	1	220V	1HP	USED 24 HOURS A DAY

- **Location: Bar Restaurant**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
LAMP	5	220V	50W	USE DURING BUSINESS HOURS AND AS NEEDED
	3	220V	16 W	
		220V	16W	
AIR BLOWER	15	220V	65W	USE DURING BUSINESS HOURS AND AS NEEDED
TELEVIION	1	220V		SEASONAL USE
FREEZER 600L	1	220V	210W (1.65A)	USED 24 HOURS A DAY
FREEZER 590L	2	220V	1,7 A	USED 24 HOURS A DAY
TELEVISION	1	220V		
GAS OVEN	1	220V	2 .5A	USE DURING BUSINESS HOURS AND AS NEEDED
POWER SOCKET	18	220V		

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EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
COMPUTER	2	220V	60W	USE DURING BUSINESS HOURS AND AS NEEDED
POWER SOCKET				
SPOTLIGHT				

- **Location: Sales station**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
LAMP	13	220V	10W	USE DURING BUSINESS HOURS AND AS NEEDED
AIR BLOWER	7	220V	65W	USE DURING BUSINESS HOURS AND AS NEEDED
REFRIGERATOR	1	220V	310W (2.8A)	USED 24 HOURS A DAY
	1	220V	70W (0.67A)	
FREEZER	1	220V	2,1A	USED 24 HOURS A DAY
	1	220V	1,7 A	USED 24 HOURS A DAY
COMPUTER	3	220V	60W	USE DURING BUSINESS HOURS AND AS NEEDED
POWER SOCKET	11	220V		MISCELLANEOUS USE

- **Location: African kitchen**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
LAMP	14/5	220V	16/24W	TO BE USED DURING THE NIGHT
FREEZER 600L	3	220V	2,1A	USED 24 HOURS A DAY
PEPPER MILL	1	380V	4KW	TO BE USED ABOUT 4 TIMES A DAY
POWER SOCKET	8	220V		
AIR BLOWER	2	220V	65W	USE DURING BUSINESS HOURS AND AS NEEDED

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- **Location: sheepfold**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
LAMP	05	220V	10W	USE DURING THE NIGHT
POWER SOCKET	01	220V		
BRF (electric motor)	01	380V	11kW	

- **Location: Turkey guinea fowl garden etc**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
LAMP	12	220V	16 W	USE DURING THE NIGHT
	14	220V	36 W	
	11	220V	24 W	
POWER SOCKET	01	220V		
PUMP	1	220V	750W	GARDENING USE, STARTS IF NEEDED
AIR BLOWER	1	220V	65 W	

- **Location: Pig farm**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
LAMP	12	220V	10W	USE DURING THE NIGHT
	01	220V	18W	
POWER SOCKET	01	220V		

- **Location: Hatchery**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
LAMPS	3	220V	16 W	
	1	220V	18W	
hatchery	2	220V	7,3/0,21A	
	2	220V	10,6A/0.21A	
POWER SOCKET	5	220V		

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- **Location: Dormitory LOT 2 (R+1)**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
LAMP	172	220V	16/18W	
POWER SOCKET	44	220V		
AIR BLOWER	44	220V	65W	

- **Location: Dormitory LOT 3 (R+1)**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
LAMP	172	220V	16/18W	
POWER SOCKET	44	220V		
AIR BLOWER	44	220V	65W	

- **Location: SLA2 Dormitory**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
LAMP	72	220V	16/18W	
POWER SOCKET	44	220V		
AIR BLOWER	20	220V	65W	

- **Location: SLA1 Dormitory**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
LAMP	32	220V	10/16/18W	
POWER SOCKET	33	220V		
AIR BLOWER	8	220V	65W	

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- **Location: RIVERS Dormitory**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
LAMP	13	220V	32 W	
POWER SOCKET	10	220V		
AIR BLOWER	2	220V	65W	
TELEVISION	1	220V		

- **Location: Girls' dormitory**

EQUIPEMENTS TYPE	*Nbrs*	*VOLTAGE*	*POWER*	*OBSERVATION*
LAMP	56	220V	32 /10/16/18W	
POWER SOCKET		220V		
AIR BLOWER	36	220V	65W	

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