European Commission

Final Report Task 3.3.1

An analysis of the ongoing Smart Grid projects in Cyprus

V. Efthymiou[1,2]
G. E. Georghiou[1,2]
G. Makrides[2]
M. Patsalides[2]

[1]FOSS RESEARCH CENTRE FOR SUSTAINABLE ENERGY – UNIVERSITY OF CYPRUS
[2]PV TECHNOLOGY LABORATORY – UNIVERSITY OF CYPRUS

Release date	January 2016
Status	Final
Version	2.0

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Executive Summary

This report provides information about the ongoing Smart Grid projects in Cyprus and a qualitative assessment of their replicability and scalability is presented, along with a mapping of related technical issues they address. The projects are:

- **Geographic Information System (GIS)** (Electricity Authority of Cyprus)**:** Electricity Authority of Cyprus (EAC) is working for more than 10 years now on full blown solutions for developing a GIS system that is multi user enabled with electrical grid connectivity that gives added benefits to the users. The platform that is being developed is a combination of ArcGIS of ESRI and Schneider Electric's ArcFM that runs on top of the basic ArcGIS to give to the overall system the most wanted electrical attributes.
- **Virtual power Plant (VPP)** (Electricity Authority of Cyprus)**:** Virtual Power Plant developed by the EAC transforming private generators of sizes ranging from around 400 kVA to 1500 kVA that is currently operational through a centralised system available at the EAC SCADA control centre, offering a cold reserve approaching 40 MVA in steps varying from 1 MVA to 39.45 MVA (64 generators in total) which is the maximum available (as currently set but easily modified to the requirements of the system).
- **Charging infrastructure for Electric Vehicles** (Electricity Authority of Cyprus)**:** Electric Vehicle infrastructure for public charging has already been developed offering 16 public charging stations throughout Cyprus. The system is fully aligned with the European Union (EU) directive on the deployment of alternative fuels infrastructure 2013/0012 (COD) and the standardisation mandate to CEN, CENELEC and ETSI concerning the charging of electric vehicles M/468. The project is fully operational fulfilling all the needs of EV users in Cyprus.
- **Smart inverters with distributed control** (Electricity Authority of Cyprus)**:** The Grid Rules of Cyprus [1] are obligatory to all users of the grid and have adapted all the requirements of the European Standard EN 50160. In addition to what is included in the standard, RES generators are expected to operate their systems in accordance with the requirements of Chapter 16 of the T&D Grid Rules of Cyprus and the additional technical terms issued by the DSO to all prospective RES generators. These important technical solutions maximising the use of smart inverters in support of RES penetration are well covered in the "Final report for Task 3.1.2, Analysis of distribution grid control techniques" section 5.1 [7].
- **Advanced Metering Infrastructure** (Electricity Authority of Cyprus)**:** The Advanced Metering Infrastructure (AMI) project that is tendered out by the EAC covering two distinct areas for implementing all the possible technologies (smart meters, concentrators, MDMS management system, fibre optic, power line communication (PLC) and GPRS communication infrastructure, in house displays in full communication with the provided smart meters, integration of

the provided systems with the billing and management IT solutions of the EAC etc) is included in the analysis in order to present the most up to date results and the lessons learned through this process for identifying possible next steps.

- **SCADA Distribution** (Electricity Authority of Cyprus)**:** The EAC of Cyprus is pushing forward with the support of an external advisor, a complete SCADA / Distribution Management System (DMS) which includes a set of modules that will provide the EAC the necessary tools for the complete management of the network, both for daily work and under faulty conditions. The ultimate goal is to drastically minimize the downtime to consumers and better management of Distributed Energy Recourses (DER), aiming at the overall improvement of the offered product.
- **Net-Metering in Cyprus** (Electricity Authority of Cyprus): The net-metering policy in Cyprus concerns only residential consumers and the PV system is currently limited to 3 kWp of installed capacity. The policy allows the consumer to import energy from the grid when the production of the PV system is insufficient, to export energy to the grid when the energy yield is surplus and to self-consume energy directly from the PV system.
- **Promotion of PV energy through net metering optimization (PVNET) project** (FOSS Coordinator)**:** The project, "Promotion of PV energy through net metering optimization" (PV-NET), that aimed at developing better energy policy for the promotion of renewable energies in the Mediterranean countries, targeting the best and most cost efficient use of PV technology. The focus was on the optimization of smart energy management systems in order to create alternative economic and sustainable measures through harmonization and reassessment of existing support schemes including government subsidies and grants. The project was completed at the end of June 2015.
- **Smart net metering for promotion and cost-efficient grid-integration of PV technology in Cyprus (SmartPV) project** (FOSS Coordinator, Electricity Authority of Cyprus partner)**:** The Project "Smart net metering for promotion and cost-efficient grid-integration of PV technology in Cyprus" with the acronym SmartPV, is co-financed by the EU through the LIFE+ Programme. This Project is in line with the general and specific objectives of LIFE+ Environment, Policy, and Governance particularly as regards to contribution in implementation, updating and developing environmental policy. The SmartPV project thoroughly investigates pilot net metering schemes for cost-effective PV implementation and higher grid penetration in Cyprus of distributed generation with the target of achieving a WIN-WIN scenario for both consumers and energy utilities. The project is expected to hand over all deliverables within 2017.
- **Green+** (Electricity Authority of Cyprus Coordinator, FOSS Partner)**:** The project entitled Green+ falls under the category of Renewable energy management and optimization for small and medium scale Distributed

Generators in rural environment with predominant solar generation: 20MWe on Low Voltage (LV) network + 50 MWe on Medium Voltage (MV) network. The project will cover all technologies to develop a multi-microgrid system with 20 MWhrs of storage for facilitating RES penetration to meet the energy needs of the rural areas of Cyprus.

1. Introduction

Cyprus is electrically isolated from the rest of Europe but fully developed with grid connectivity throughout the island with a backbone system running at 132 kV. Supply is currently achieved through three power stations situated in the south coast of Cyprus with overall capacity well above the maximum demand of the country, hence safeguarding a very high level of security of supply throughout the year.

The ongoing smart grid projects in Cyprus are analysed below in a universal methodology that will offer consistency and a base reference to facilitate the assessment for replicability and scalability.

As presented below the projects are analysed using a step by step approach for:

- Identifying the targeted functionalities through the conducted projects;
- Link the identified functionalities to the assets used or targeted to use in order to deliver the declared functionalities and judge performance that can be replicated and scaled up to meet possible roll out policies;
- Relate the quantified functionalities to anticipated benefits and judge incentives for further investment utilising the replicability and scalability judged through the performance of the assets used.

2. Projects

2.1 Geographic Information System (GIS) (EAC [3])

The Electricity Authority of Cyprus is working for more than 10 years now on full blown solutions for developing a GIS system that is multi user enabled with electrical grid connectivity that gives added benefits to the users.

The platform that is being developed is a combination of ArcGIS of ESRI and Schneider Electric's ArcFM that runs on top of the basic ArcGIS to give to the overall system the most wanted electrical attributes as shown in the Figure below.

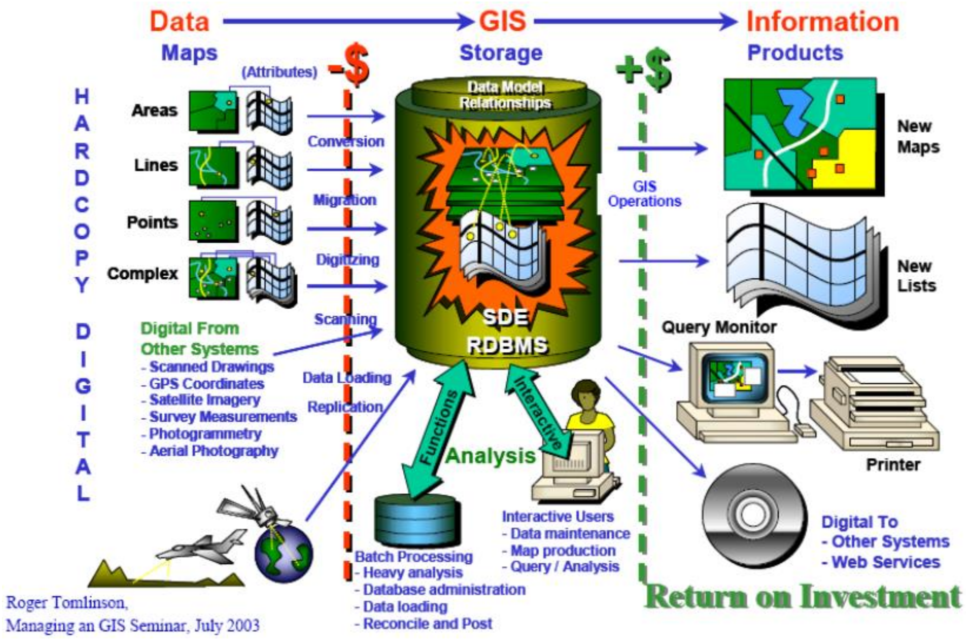


Figure 1. GIS platform block diagram.

Through the built up system, innovation in the design process is achieved, as the design is sent to SAP and Work Orders are created automatically, while scheme template changes are updated 'as built' and are then promoted to final asset record, as shown in the Figures below:

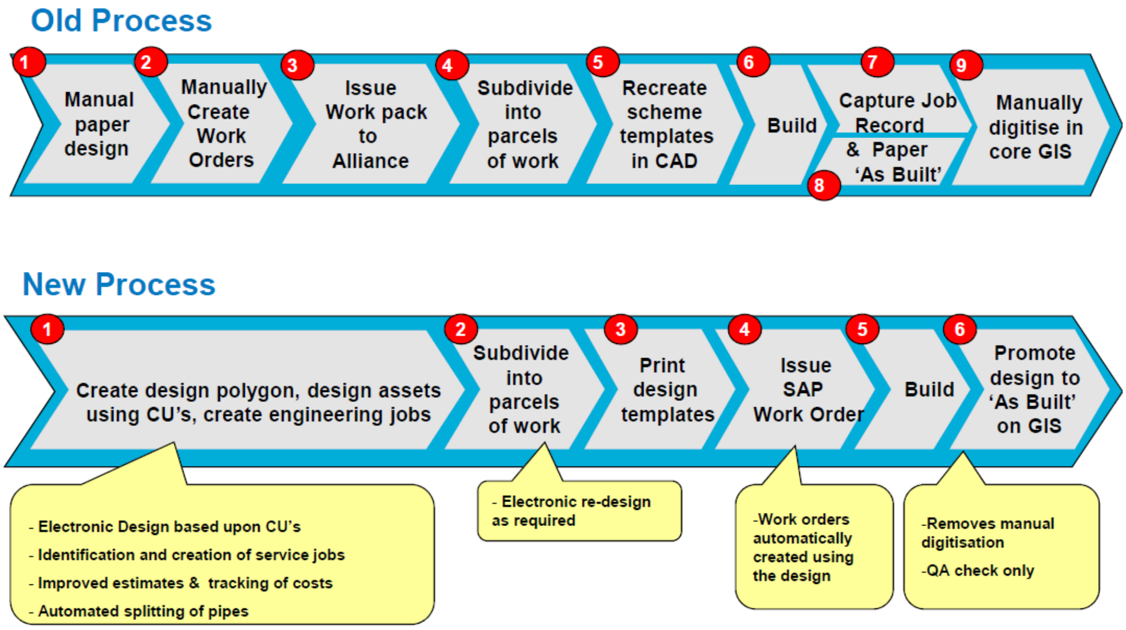


Figure 2. ArcFM Designer – Design sent to SAP and Work Orders automatically created in SAP.

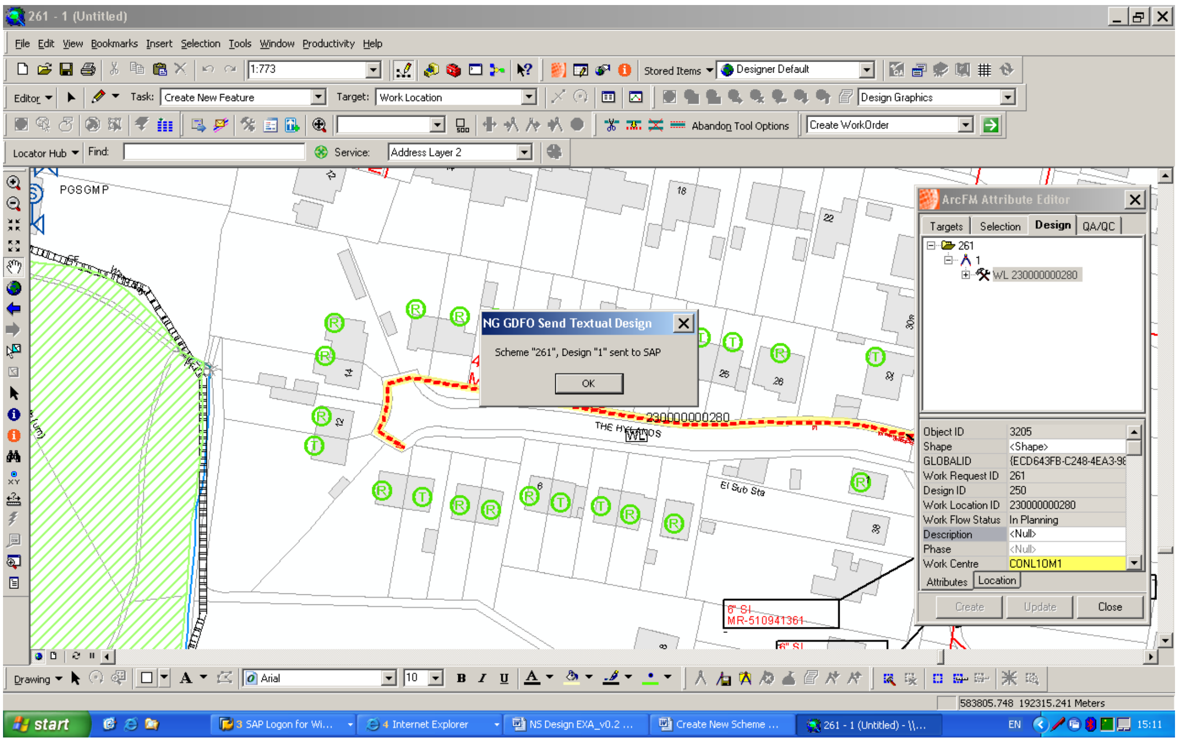


Figure 3. ArcFM Designer – Scheme Template Changes updated 'as built' and then promoted to final asset record.

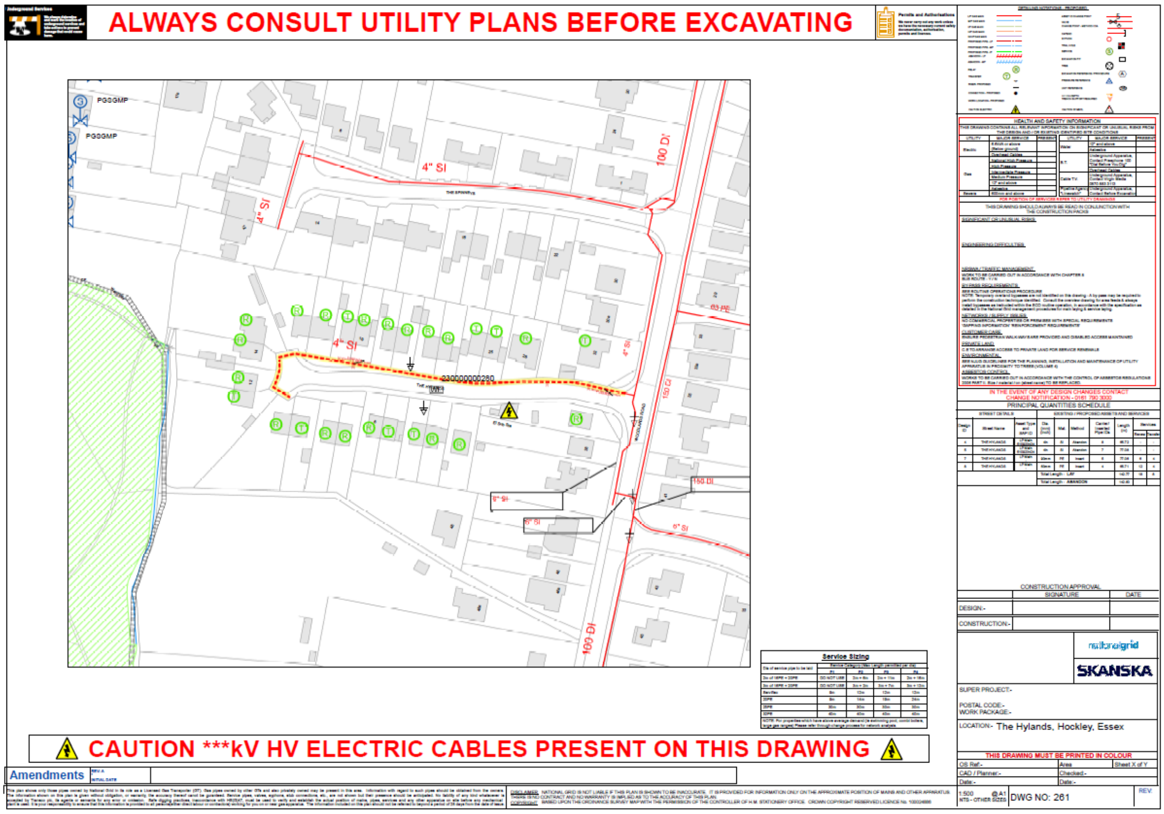


Figure 4. GIS is complete covering all voltages offering services to all sections of the utility.

The system as developed addresses all the voltage levels of the grid to the required detail that the users have identified. The effort for digitizing all voltage levels and related infrastructure of the grid is enormous. Work for GIS is nearly complete capturing all the work that was previously done manually. Links have been created between the SAP environment and the PLSCADD (land survey and design of overhead lines) environment giving flexibility and productivity to all sections of the company. Connectivity is possible with:

- Land survey and design – PLSCADD
- System design and analysis – DIgSILENT
- Projects and scheme management – SAP
- Human resources – SAP
- Material management – SAP
- Customer care and billing – CC&B
- System control and data acquisition - SCADA

Pending work is related to the last mile connectivity which is critical to the end result. This is expected to be fully delivered by the end of 2016 meaning that all the work towards the evolution of smart grids will greatly enhanced.
Typical work within the environment of the GIS system is presented in the Figure below providing an indication of the captured detail that is so important for the work of grid companies.

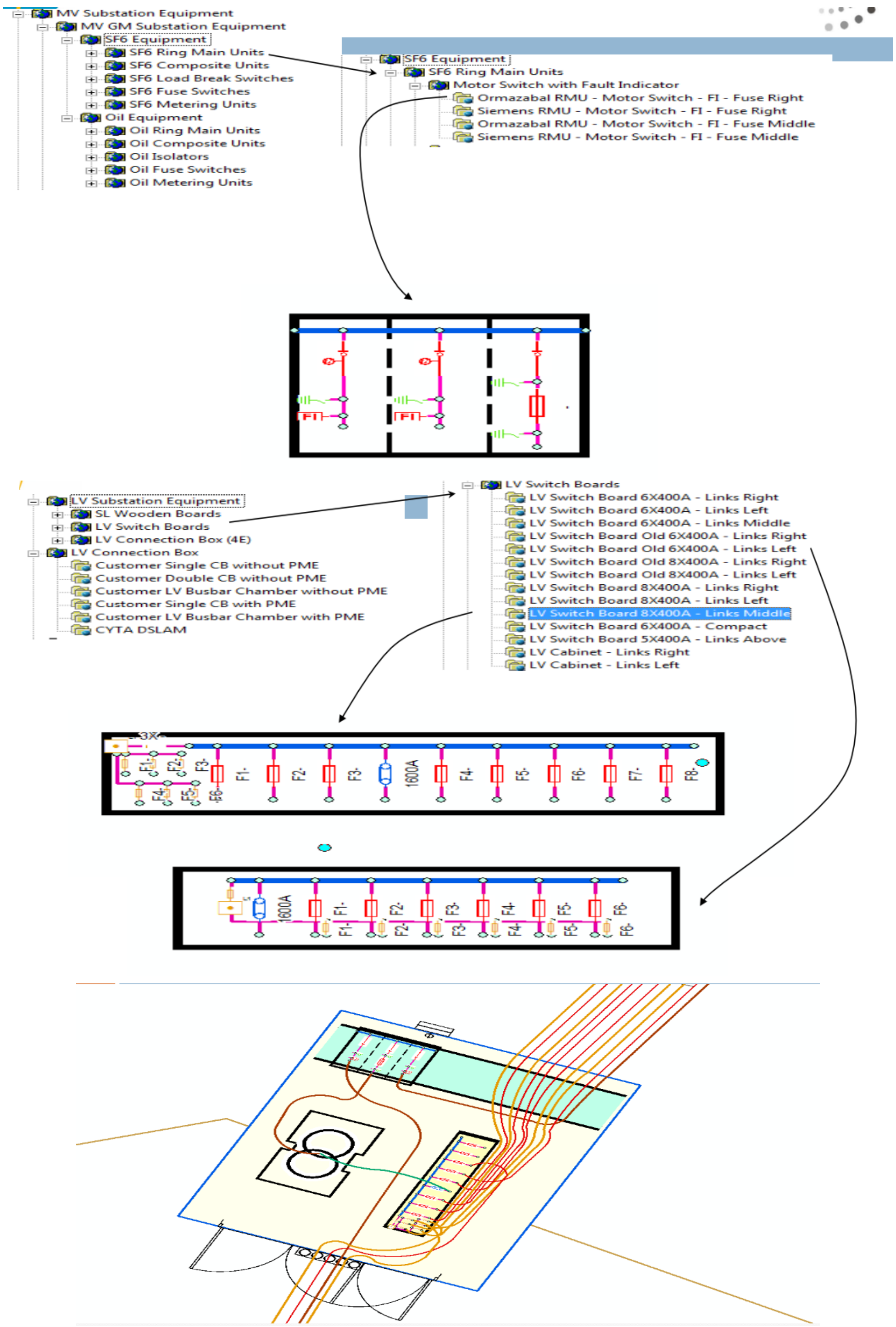


Figure 5. Typical schematics of the medium voltage network showing extracts of the layouts used and the connection details of equipment.

2.2 Virtual Power Plant (VPP) (EAC)

Virtual Power Plant developed by EAC transforming private generators of sizes ranging from around 400 kVA to 1500 kVA that is currently operational through a centralised system available at the EAC SCADA control centre, offering a cold reserve approaching 40 MVA in steps varying from 1 MVA to 39.45 MVA (64 generators in total) which is the maximum available (as currently set but easily modified to the requirements of the system).

The project started when the Regulator of Cyprus has instructed EAC to utilise existing generating sets already installed in various consumers' premises for the purpose of gaining additional generating capacity in the form of cold-reserve. The consumers/producers who chose to participate in this scheme were offered various incentives including preferential tariff and/or additional security of supply warranties. The system, called Virtual Power Plant (VPP), is planned to be utilised in the following situations:

- As cold reserve during unexpected generation outages in order to assist in system frequency recovery and/or stability.
- During the hours of peak energy demand in order to address the problem of increased consumption especially during the hot summer months.
- As a uniform Power Generating Plant that will be committed along with the rest of the available generation according to Transmission System Operators unit commitment policy in a pre-programmed schedule.

Generation sets utilize either of the following topologies:

- In full synchronization with the unit connected to the LV network of EAC's distribution network. A synchronizing scheme has been employed to ensure smooth synchronization of each generator following the issue of the appropriate remote command.
- In isolation, the generating set will be fired up to undertake the load of the establishment where it is installed by means of an automatic change-over switch that will be operated locally by the authorised representative of the owner. This will effectively offload the Grid with the equivalent load of the particular establishment at the time the command is issued.

2.2.1 Signals

The following signals, summarized in the Table below, were included for the safe control and monitoring of the generating sets. Signals categorized as "minimum" were mandatory while those shown as "additional" were regarded as desirable. The implemented system included all the signals referred to below except the "Fuel availability indication". The installed Smart meters facilitate the transmission of these signals from/to the generators.

Table 1. Signals included for the safe control and monitoring of the generating sets.

Signal name	Description	Type	Category
Eng_start	Engine start remote command *1	Command	Minimum
Eng_stop	Engine stop remote command *2	Command	Minimum
Fuel_Status	Fuel availability indication	Binary indication	Additional
Eng_running	Engine running indication	Binary indication	Minimum
Remote_supervisory	Remote / Supervisor status	Binary Indication	Minimum
Engine_start_fail	Engine Failure indication	Binary Indication	Minimum
General_Alarm	Engine general alarn (cascaded temperature, mechanical, other alarms)	Binary Indication	Minimum
Engine_Available	Availability indicatio	Binary Indication	Additional
Load_on_engine	Load on engine indication	Double Indication	Minimum
Engine_Load_Measurement	Load current measurement	Analogue measurement (Amp:	Minimum
Energy_measurement	Energy measuremen	Analogue measurement (kWh)	Minimum

Note 1: The Eng_start command will initiate the following procedure which will be implemented by means of local automation devices:

1. Activation of local audible and visual warning indicating the imminent start of the generator
2. 15 sec delay
3. Engine start-up
4. Deactivation of the audible warning
5. Circuit breaker / change over switch activation

Note 2: The Eng_stop command will initiate the following procedure which will be implemented by means of local automation devices.

6. Deactivation of Circuit breaker / change over switch
7. 10 sec delay
8. Engine shutdown
9. Deactivation of the visual warning

The Figure below shows a schematic of how private generators are connected through a synchronizing panel to the grid.

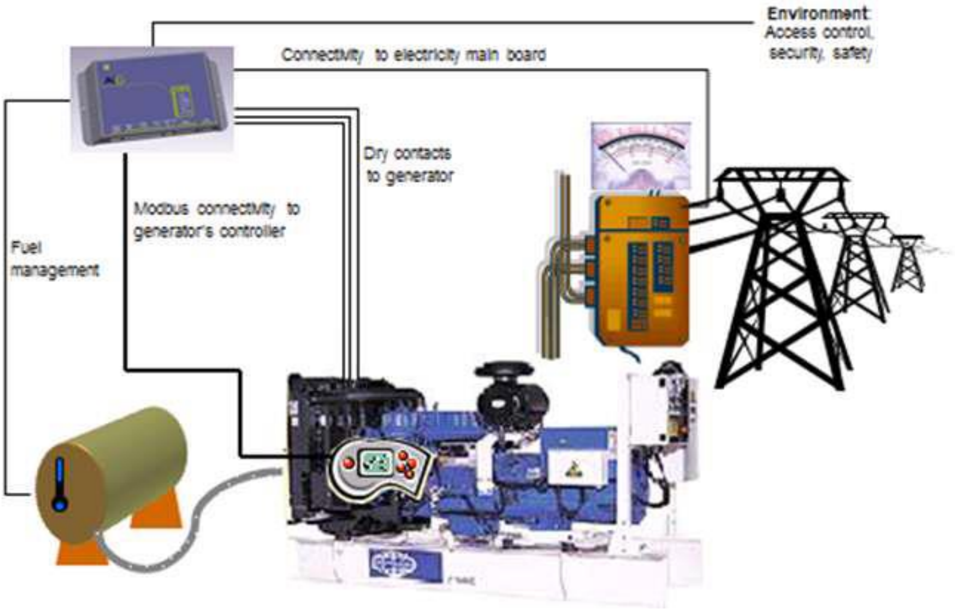


Figure 6. Schematic of how private generators are connected through a synchronizing panel to the grid.

Additionally, the Figure below shows how the main apparatus interconnected with a central server at the premises of the DSO.

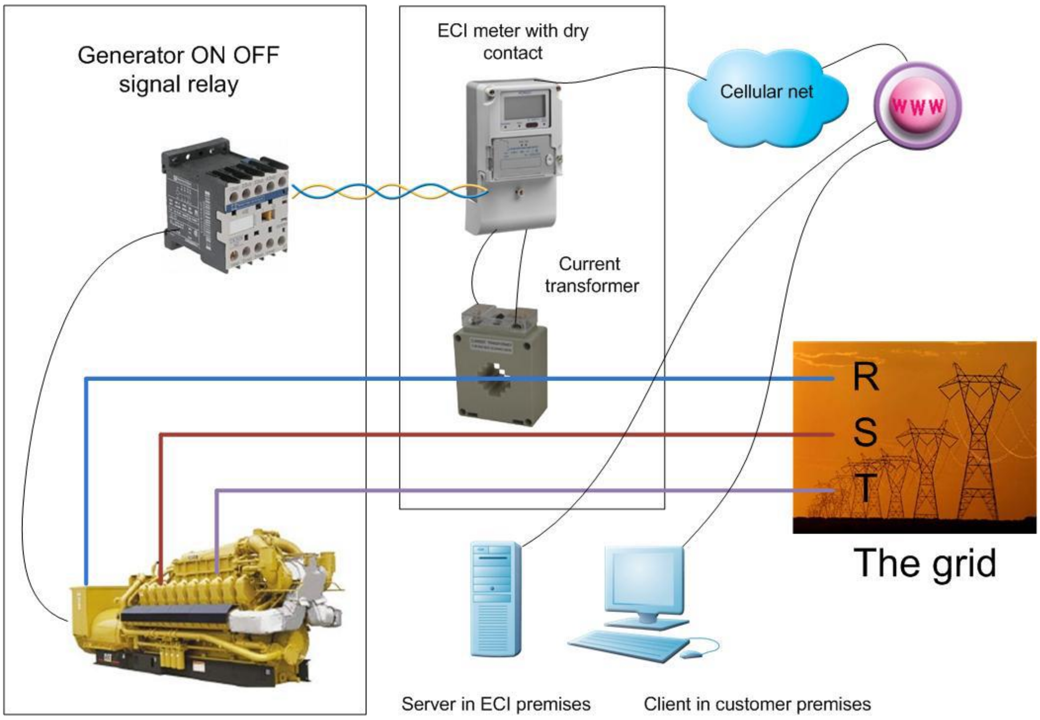


Figure 7. Schematic of apparatus interconnections with a central server of the DSO.

The typical single line diagram of the synchronization circuitry is shown below.

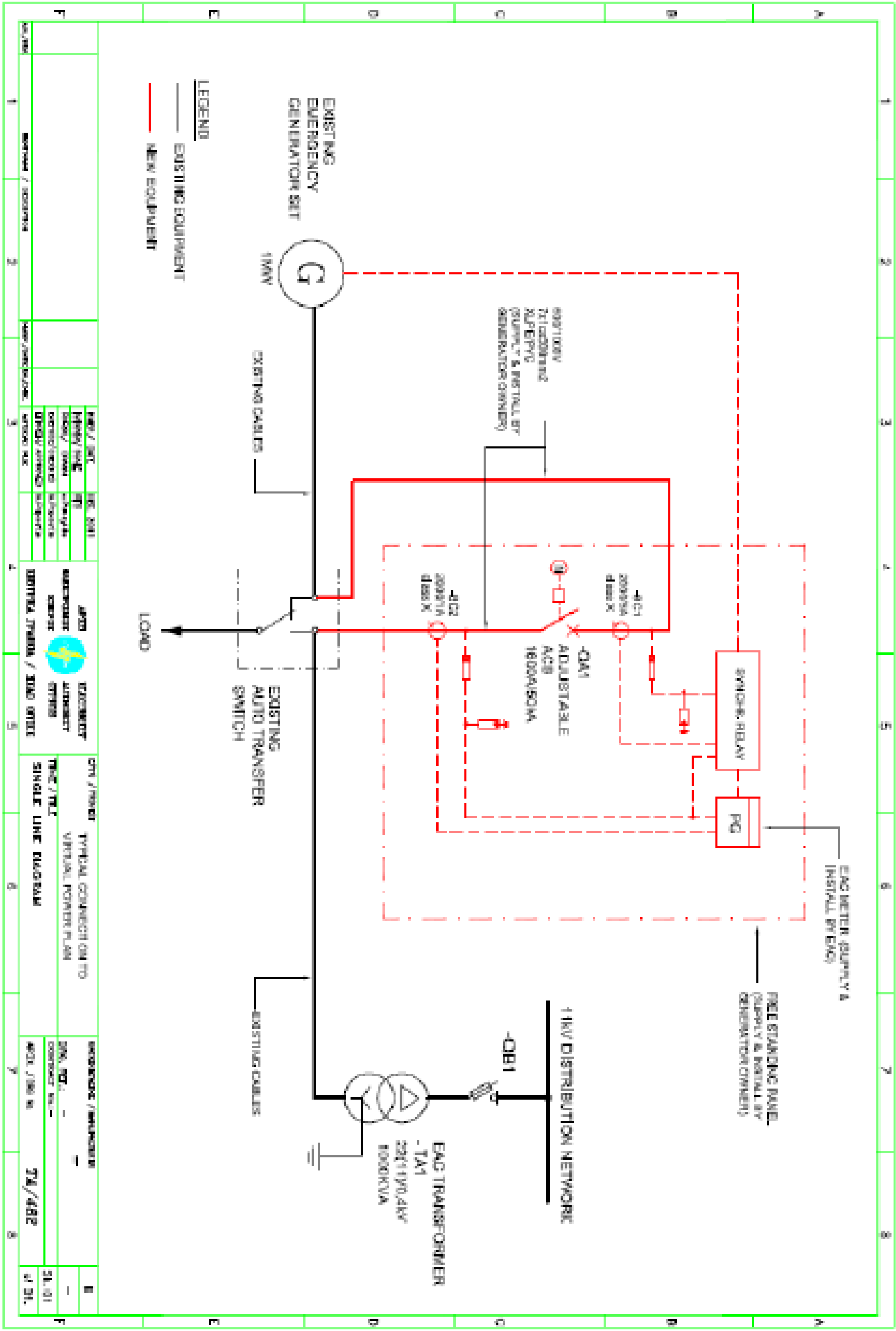


Figure 8. Typical single line diagram of the synchronization circuitry.

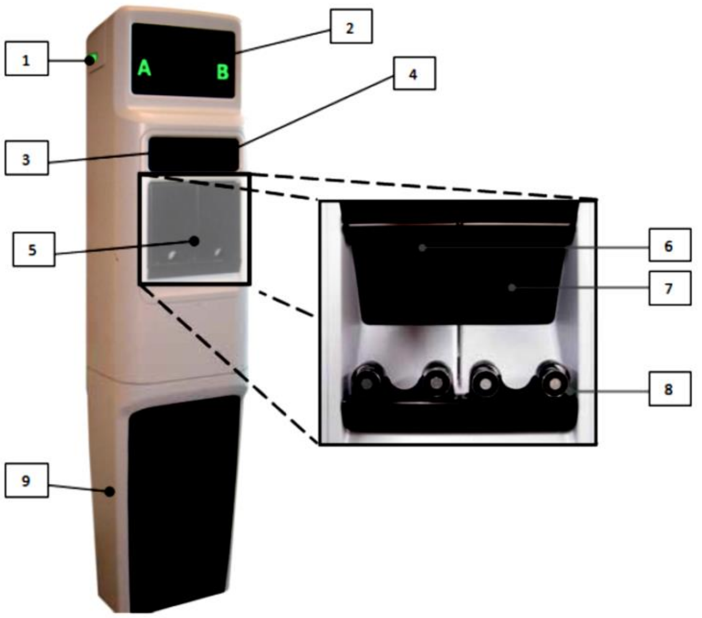
2.3 Charging infrastructure for Electric Vehicles (EAC)

Electric Vehicle infrastructure for public charging has already been developed offering 16 public charging stations throughout Cyprus. The system is fully aligned with the EU directive on the deployment of alternative fuels infrastructure 2013/0012 (COD) and the standardisation mandate to CEN, CENELEC and ETSI concerning the charging of electric vehicles M/468. The project is fully operational fulfilling all the needs of EV users in Cyprus.

The infrastructure deployed is based on the international standard IEC 61851 covering modes of charging, cables and terminal points. The EAC has adapted the following policy on the provided terminal charging points (MODE 3 (Charging AC)):

- Specially adapted access points;
- Slow and semi-fast charging (3,6/7,2/21kW max);
- Plugs in accordance with IEC 62196-2;
- Industrial charging accessories type 2 (AC charging);
- Mode 3 charging options with 21kW max.

The technical parts of the on-site charging station are detailed in the Figure below.



1. Rear Beacon	2. Charge Status indicator	3. Liquid Cristal Display
4. RFID Reader	5. Vandal doors	6. Plug A – Type 2
7. Plug B – Type 2	8. Electromagnet	9. Base

Figure 9. Charging station technical details.

The available charging options are presented in detail in the Table below.

Table 2. Available charging options summary.

Application	Nominal voltage	Charging time	Battery size
Charging station 16A	1Ph 230V AC 3,6 kW	6 hrs	22 kWhrs
Charging station 32A	1Ph 230V AC 7,2 kW	3 hrs	22 kWhrs
Charging station 32A	3ph 230V AC 21 kW	1 hr	22 kWhrs

The Figure below shows a typical charging station in Nicosia, Cyprus.

Figure 10. Typical charging stations in Cyprus.

All registered Electric Vehicle users are issued an electronic card for the charging process, see Figure 11.

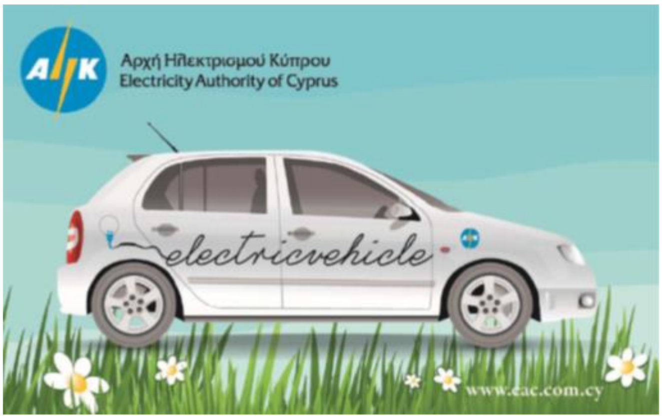


Figure 11. Electronic card for charging.

The 16 charging stations are in operation in public places throughout Cyprus and these are shown in the map below.

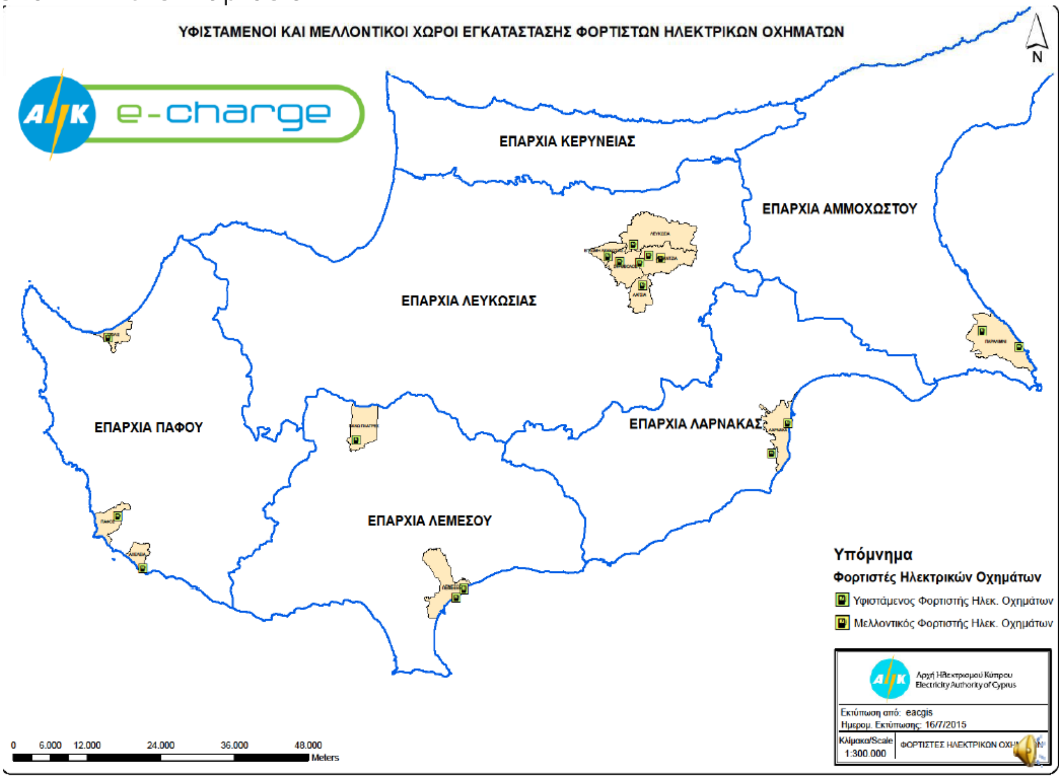


Figure 12. Installed EV charging station in Cyprus.

The central e-charge management system offers full capabilities for managing the needs of the users:

- Manages charging options
- Allocates level of local charging depending on system and / or EV possibilities
- Automatic transfer of charge to the Customer Care and Billing back system of the Supplier EAC,
- Remote control of charging including tele control,
- Visualisation of quality of supply,
- Instant recording and annunciation of faults,
- Protection from intruders.

The system as designed is capable of handling full coverage of Cyprus since it is based on the open charge point protocol (OCPP) and fulfils European standards of connectivity. Currently all 18 available EVs in Cyprus (NISSAN, RENAULT and TESLA) are using the deployed infrastructure. Smaller electric vehicles (REVA etc) are utilising smaller in home systems of their own. Up to now private charging stations meeting open European protocols have not been commissioned and this is part of the future planning of the Authorities in Cyprus.

The drawings depicted in the Figures below show extracts of the capabilities of the central management system for e-charge. In particular, the Figure below shows the central map of the charging stations management system.

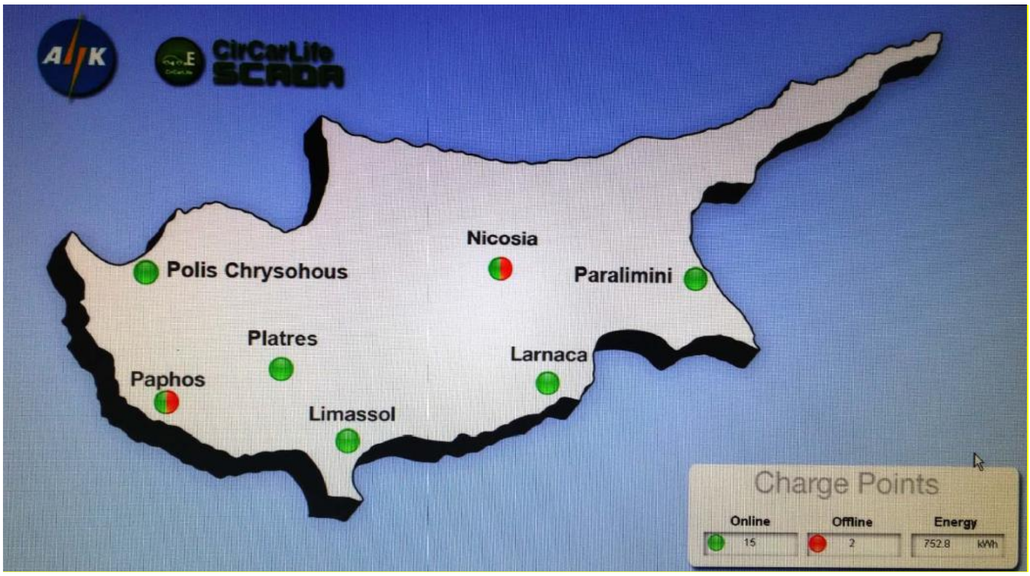


Figure 13. A central map in the management system showing the siting of the available charging stations.

The Visual display of the User at the charging station, with indication of all available options is shown in the Figure below.

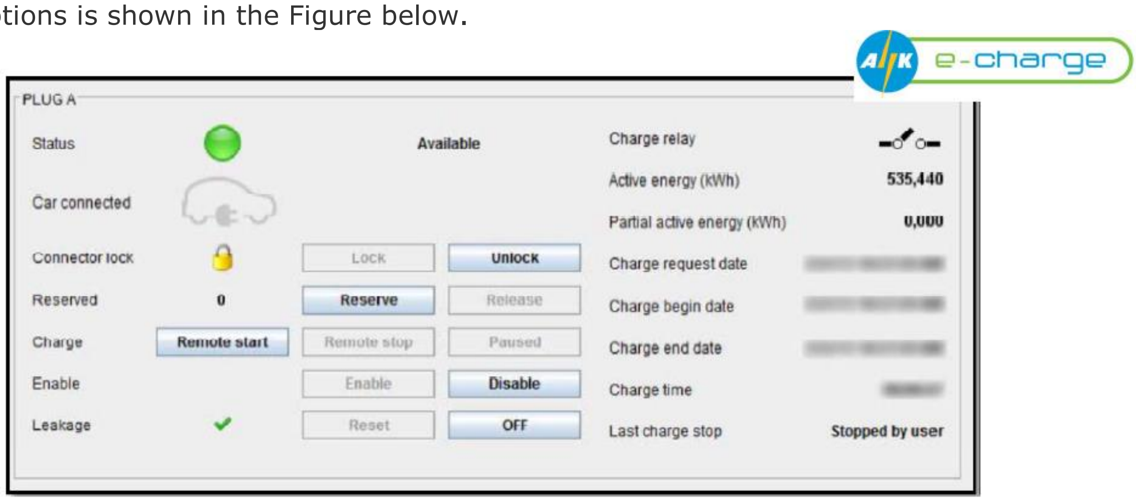


Figure 14. The visual display available to the user with indication of available options.

To summarize, the e-charge service is made available to all owners of EVs with the following details:

- Charging possibilities at all the charging points installed throughout Cyprus;
- Charging of units used are based on Tariff no 15, (€5,27/bi-monthly basic charge and 15,96 cent/kWh with basic fuel cost €300/M.T.);
- Billing is bi-monthly;
- Safety and security of supply during charging;
- Every user requires to sign a supply contract with an initial deposit of €25 which will be charged on the first received bill.

Next steps of public charging implementation:

- Agree strategy for extension of available infrastructure
- Draft a special tariff for charging of EVs for approval by CERA [4];
- Draft policy proposals in support of e-mobility;
- Develop an application for smart phones, to assist the users for the nearest available charging station;
- Ability for issuing a reservation request through a smart phone;
- Pay charge cost through smart phone or credit card;
- Develop friendly to use application allowing access to useful feedback information on charging practices of users.

2.4 Smart inverters with distributed control (EAC)

The Grid Rules of Cyprus [1] are obligatory to all users of the grid and have adapted all the requirements of the European Standard EN 50160. In addition to what is included in the standard, RES generators are expected to operate their systems in accordance with the requirements of Chapter 16 of the T&D Grid Rules of Cyprus and the additional technical terms issued by the DSO to all prospective RES generators. These important technical solutions maximising the use of smart inverters in support of RES penetration are well covered in the "Final report for Task 3.1.2, Analysis of distribution grid control techniques" section 5.1 [7].

2.5 Advanced Metering Infrastructure (AMI) (EAC)

The Advanced Metering Infrastructure (AMI) project that is tendered out by the EAC covering two distinct areas for implementing all the possible technologies (smart meters, concentrators, MDMS management system, fibre optic, PLC and GPRS communication infrastructure, in house displays in full communication with the provided smart meters, integration of the provided systems with the billing and management IT solutions of the EAC etc) is included in the analysis in order to present the most up to date results and the lessons learned through this process for identifying possible next steps.

The energy sector in Cyprus is going through different challenges such as the following:

- Isolated energy system
- High dependence on imported fossil fuels
- High cost of imported primary energy
- Seasonal fluctuations in energy demand
- Peak demand makes use of valuable assets only for a short time in a year,
- Environmental constraints

However, Cyprus has developed its energy policy to overcome the different challenges and has committed to a RES target and energy efficiency plan. The government confirms through regular reports that the targets for Cyprus will be met (13% of RES energy use (16% of electricity use to be RES generated) and 20% efficiency improvement by 2020). Priorities include: maximizing the efficient use of domestic resources of renewable energy, saving in energy in primary form and in energy end-use, growth of energy awareness and finally making efficient use of energy by putting into place mechanisms that give incentives to users.

As has been proven in other countries around the world, process innovations that combine advanced metering and communications technologies (commonly referred to as Advanced Metering Infrastructure or AMI) have the potential to dramatically improve economic efficiency and productivity of distribution and supply businesses, as is the case in Cyprus. Therefore, the case for introduction of AMI in Cyprus has attracted the interest of the sector's stakeholders and especially the EAC who is responsible for the distribution supply of electricity in the country.

The AMI pilot system will consist of 3,000 smart meters. Ahead of the tender a policy & strategy report was drafted [1]. The aim of the policy & strategy report was to get a clear picture of the following aspects:

- Market drivers for AMM (Advanced Metering Management) in Cyprus;
- EAC organisation and business processes related to meter data management, including meter ownership;
- Current metering systems and architectures in use, including the new Meter Data Management System (MDMS);
- Specifics of the EAC grid;
- Available telecommunication services and planned initiatives;
- High level functional requirements of the planned full scale AMI system;
- Customer requirements and expectations with respect to smart meters;

After collecting stakeholder views in a series of meetings and based on the elaboration of the different EAC team members, the following Table of functional requirements was derived for the AMI pilot system.

Table 3. Functional requirements for the AMI pilot system.

Business requirements	Objective	Priority	Functional requirements	Category
Eliminate manual reading costs	Reduce costs and enhance revenue	High	Remote reading	Minimum
Ability to perform scheduled or on demand reading	Enhance billing collection	High	Remote reading	Minimum
Immediate visibility into the customer actual meter registers will reduce customer complaints and phone calls to the call center.	Enhance customer satisfaction	High	Remote reading	Minimum
Fraud detection	Revenue protection	High	Two way communication	Minimum
Outage detection	Security of supply	High	Two way communication	Minimum
Remote diagnostics/firmware upgrades	Reduce site visits and enhance revenue	High	Two way communication	Minimum
Ability to check and read the quality of supply on a certain connection	Meeting regulatory requirements	High	Two way communication	Minimum
Applying of TOU	Reduce Peak demand	Low	Advanced tariffing and payment	Advanced
Ability to connect and disconnect supply on a certain connection	Enhance revenue collection	High	remote disablement & enablement of supply	Minimum
Replacement of ripple control	Reduce Peak demand	High	remote disablement & enablement of supply	Minimum
Load management control (heating, air-conditioning, street lighting)	Reduce Peak demand	High	Communications with home devices	Minimum
Energy storage (PEV)	Security of supply	Low	Communications with home devices	Advanced
Ability to read water meters to provide services to municipalities	Provide multi metering services	High	To support LAN communications	Advanced
Offer new value added services to customer (information messages)	Increase service level and customer satisfaction	Low	Gateway to in-home display	Optional
Local appliances shall have the ability to receive the actual energy consumption and production.	Energy efficiency	Low	Gateway to in-home display	Advanced

The functional requirements were based on the business requirements and objective that EAC would like to accomplish by the implementation of the AMI pilot system. A classification of those requirements as minimum, advanced or optional shows if a requirement is necessary to implement or could be considered as future requirement (for the large roll-out of Smart Grids implementation), or just a nice-to-have functionality that could be implemented if time and budget would allow it.
Further in the process of identifying the AMI pilot system policy, the functional telecom architecture for the AMI implementation has been identified and technology options have been investigated. The telecommunications architecture that was selected is strongly aligned with the OPEN Meter architecture to ensure compliance with European standards and interoperability between the equipment from different vendors. Furthermore the architecture was selected to form the basis of a future Smart Grid architecture, and is therefore inherently future proof.

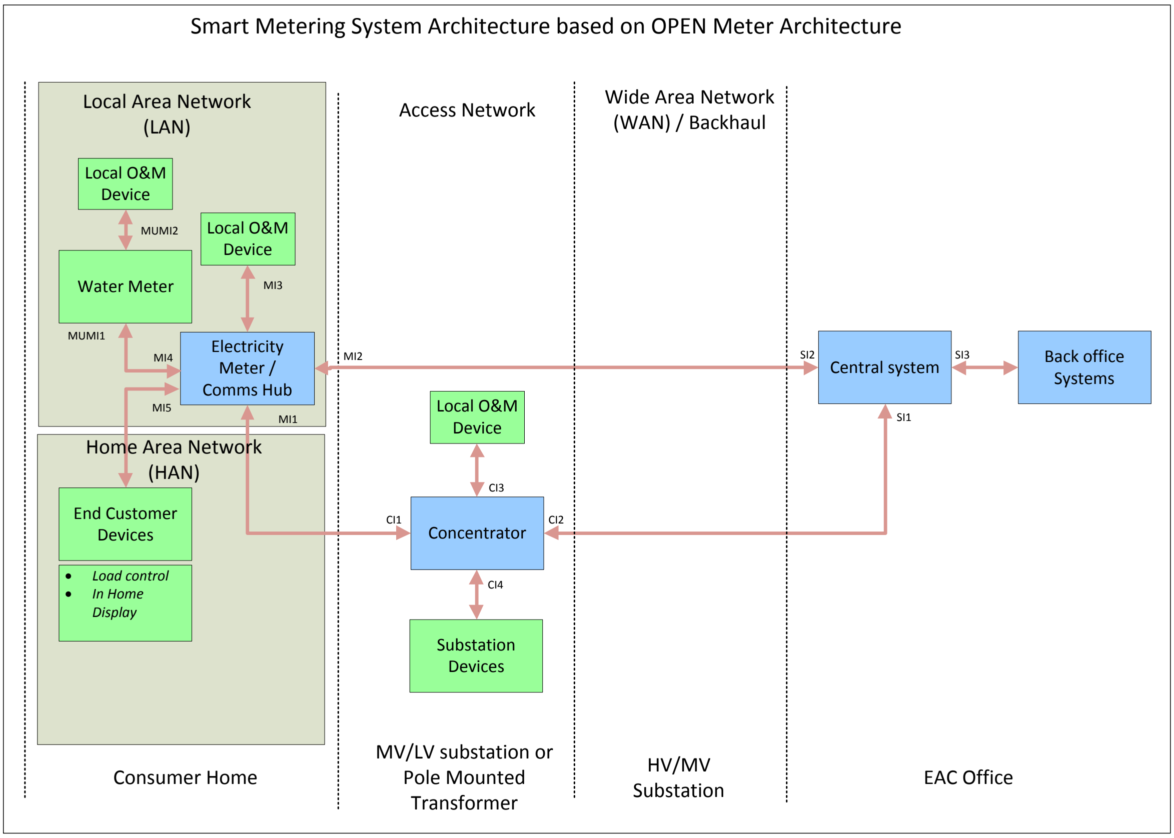


Figure 15. Smart metering architecture based on OPEN meter architecture.

Following an extensive review and evaluation of current telecommunications technologies and standards, three different solutions were identified for inclusion in the AMI pilot system as shown in the Table below.

Table 4. Telecommunication technology and standards for AMI pilot.

Interface	Selected Technology Type	Solution 1 (Urban areas)	Solution 2 (Urban & Remote Areas)	Solution 3 (Remote Areas)
MI5	Wireless	(1) Zigbee (2) WiFi	(1) Zigbee (2) WiFi	(1) Zigbee (2) WiFi
MUM1 – MI4	Wireless	(1) Zigbee (2) IEE 802.15.4 WiFi	(1) Zigbee (2) IEE 802.15.4 WiFi	(1) Zigbee (2) IEE 802.15.4 WiFi
MI2 – SI2	Wireless			GPRS / UMTS
MI1 – CI1	PLC	Narrowband PLC (high data rate)	Narrowband PLC (high data rate)	
CI2a – SI1a	Wireless		GPRS / UMTS	
CI2b – SI1b	PLC + Fibre	1) Narrowband PLC (high data rate) + fibre 2) BPL + fibre		

For each of the three application areas (Urban, Remote and Combined Urban / Remote), specific PLC and wireless technologies have been selected for each of the communication interfaces identified in the telecommunications architecture. The recommended technologies were selected on the basis of their:

- Technical feasibility (in terms of data capacity, coverage and data speed)
- Cost effectiveness (CAPEX and OPEX)
- Support for interoperability (standardization)
- Alignment with EU recommendations

It has been also decided that Broadband PLC will be specifically included in Pilot to determine technical and financial feasibility for EAC, so that their existing fibre backbone infrastructure can be fully leveraged.

2.6 SCADA Distribution (EAC)

The EAC of Cyprus is pushing forward *with the support of an external advisor*, a complete SCADA / DMS (Distribution Management System) which includes a set of modules that will provide the EAC the necessary tools for the complete management of the network, both for daily work and under faulty conditions. The ultimate goal is to drastically minimize the downtime to consumers and better management of Distributed Energy Recourses (DER), aiming at the overall improvement of the offered product.

The Project aims the following objectives:

- Monitoring, Control and Operation of the Distribution System.
- Safe, reliable and efficient operation of the Medium and Low Voltage Distribution Network.
- Improve response and minimize downtimes of service interruptions.
- Improve EAC´s quality of service to clients.
- Data acquisition and historical information for alarms, events and system operations
- Optimization of Network performance for accommodating high RES penetration.
- Accurate and reliable Performance Indices for comparison with other European countries.
- Improve performance of the network through minimization of losses.
- Meeting regulatory requirements.

2.6.1 Network and System Information

Cyprus's Transmission Network (132 and 66kV) and part of 22/11 kV Distribution Network is monitored, operated and controlled by the Transmission System Operator (TSO) who is responsible for the operations of the Transmission Network. The ABB SPIDER-400 Rel.10.5 SCADA/EMS system has been in service since 1997 and has been recently updated to ABB Network Manager Version 6.4. The existing SCADA system covers the Generation and Transmission System up to and including the Circuit Breakers of the MV (22/11 kV) outgoing feeders in all HV/MV Transmission Substations.

The Distribution Network (MV and LV) is managed by EAC and is divided into four Areas of Responsibility hereafter called Areas:

- The Nicosia-Kerynia-Morphou Area
- The Limassol Area
- The Paphos Area
- The Larnaca-Famagusta Area

The above Areas of responsibility largely coincide with the corresponding Geographical Counties with a few exceptions.

EAC has no control of the Network in the areas north of the confrontation line in which the government does not exercise effective control as a result of the Turkish invasion and occupation since 1974.

The area of Responsibility for each of the Areas covers all Medium and Low Voltage Network of the Area starting from the MV circuit breaker of the outgoing feeder in the Transmission Substations which is currently monitored and controlled by the ABB Network Manager Version 6.4.

Each of the above four Areas is exclusively responsible for its corresponding Distribution Network regarding:

- Operations
- Maintenance
- Network planning
- Network reinforcement and expansion
- Customer Service

There are clear and well defined electrical and Geographical boundaries between the Areas and only Authorised personnel from each Area is allowed to carry out operations, maintenance or interfere with the Network in anyway within their Area of responsibility. There are various levels of authorisations regarding both the Voltage levels as well the level of competency. All Authorisation Certificates are issued and valid for a certain Area of responsibly only and no cross-Area operations are allowed.
The Authority's Distribution Network consists of but is not limited to the following equipment:

- Transmission/Distribution 132/11kV Substations 64 Nos.
- MV Overhead Lines (11/22kV) 5777.3 km
- MV Underground Cables (11/22kV) 3696.6 km
- LV Overhead Lines (400V) 9669.7 km
- LV Underground Cables (400V) 5686.7 km
- 22000-11000/400V Pole Mounted Transformers 9933 Nos
- 22000-11000/400V Ground Mounted Transformers 6149 Nos
- Automatic Reclosers
- Voltage regulators.
- Pole mounted Disconnectors.
- Static equipment for generation/absorption of Reactive power.

The annual growth of the Distribution System during the last few years is estimated to 3% annually.

2.6.2 Distribution Network

The Network Business Unit of the Electricity Authority of Cyprus is the owner and operator of the Distribution System in accordance with the recently revised Electricity Law. The specific responsibilities, rights and obligations related to the (DSO) resulting from the Electricity Law create special needs to maximise benefits for the consumers and the economy. The Distribution System as a natural monopoly requires strict regulation in order to achieve the targets set by the European Union and the Cyprus Government.
The Distribution Network Unit aims towards the best technological solutions to enhance the quality and reliability of supply of electricity at the lowest cost. The need for the latest, state of the art combination of telecoms, IT and system integration is crucial, especially with the increasing penetration of distributed generation and the development of bidirectional communication between prosumers, suppliers and the Distribution System Operator. The conditions are gradually being established for the evolution into a smart grid with all the offered benefits.
Within this environment the SCADA/DMS System will support the distributed generation and load management which is expected to also cater for the specific demand of electric vehicles, heat pump systems and energy storage systems. The EAC is responsible for the operation, maintenance and development of the electricity distribution network in Cyprus ensuring transparent and non-discriminatory access for the prosumers and in general all users of the network.

Pursuant to the provisions of the legislation in force, the SCADA/DMS shall support the following obligatory operations to be performed by the EAC on:

1. Reaction to requests from prosumers:
    - New Consumer and Producer connections.
    - Modifications to existing connections.
    - Network relocation and development.
2. Network Development:
    - Reinforcement, improvement and modernization of the network.
    - Construction of Distribution Centres and necessary communication infrastructure.
3. Operation and Exploitation of the Network:
    - Operation of the Distribution Network.
    - Inspection and maintenance of the Network.
    - Outage Management.
    - Reinstatement and repair of faults.
    - Network users' service.
    - Offer of Ancillary services.
    - Supervise, control and manage of Distributed Generation.
    - Supervise, control and manage of Load Demand.
    - Supervise, control and manage of Energy Storage system.
    - Power Quality issues.
    - Consumption metering.
    - Support the TSO Cyprus and provide all necessary information for the smooth operation of the electrical system.

2.6.3 Telecommunications

The Department of Telecommunications and Electronics within EAC's Network Business Unit, deals mainly with the development and support of electronic and telecommunication systems. The existing Fiber Optic system connects via digital multiplexers the transmission substations, the power stations and all EAC offices. The system serves the needs of the existing SCADA Transmission system, Tele-protection, Telephony, Ripple Control, Information Technology and other services.

2.6.4 Existing Distribution SCADA Pilot Project

EAC has installed a SCADA/DMS system on pilot basis in the Nicosia Area office in 2003. The system LYNX was supplied by Gilam Fei, Belgium and has successfully intergraded about 150 remotely controlled network locations (RTUs) both in the underground as well as in the overhead MV network in the greater Nicosia area.
In addition:

- GSM communication links are used to access all remote RTUs (GSM Modem in RTUs and PSTN Modems at the Control Centre)
    - Protocol of communication used between the Control Centre and RTUs is the IEC 60870-5-101 and IEC60870-5-104.
- Remote Equipment consists of
    - MV Overhead Line Disconnectors with built in RTU supplied by Lucy

Switchgear, UK;
- MV Reclosers with built in RTU supplied by Nu-lec Industries, Australia;
- A number of RTUs for ground mounted substations supplied by Schneider;
- A number of pole mounted Voltage Regulator systems.

All above RTUs have been successfully intergraded to the Central SCADA system.

2.7 Net-Metering in Cyprus (EAC)

The net-metering policy in Cyprus concerns only residential consumers and the PV system is currently limited to 3 kWp of installed capacity with the intention of increasing it to 5 kWp in the near future. The connection scheme for the net-metering scheme can be found in the following figure enabled with a meter (preferably smart meter) equipped with two independent registers for recording the imported and exported energy.

The policy allows the consumer to import energy from the grid when the production of the PV system is insufficient, to export energy to the grid when the energy yield is surplus and to self-consume energy directly from the PV system.

The consumer is billed every two months based on the net amount between the import and export energy, that is:

$$Net\ energy\ (kWh) = Import\ Energy\ (kWh) - Export\ energy\ (kWh) \quad (1)$$

If the net amount is positive the net-metering consumer pays the net amount at retail price. On the other hand, if the net is negative, the prosumer earns the net energy, REC, which can be used to offset the consumption of the following billing periods. By the end of the billing year, April-May, any RECs not used are credited back to the utility.

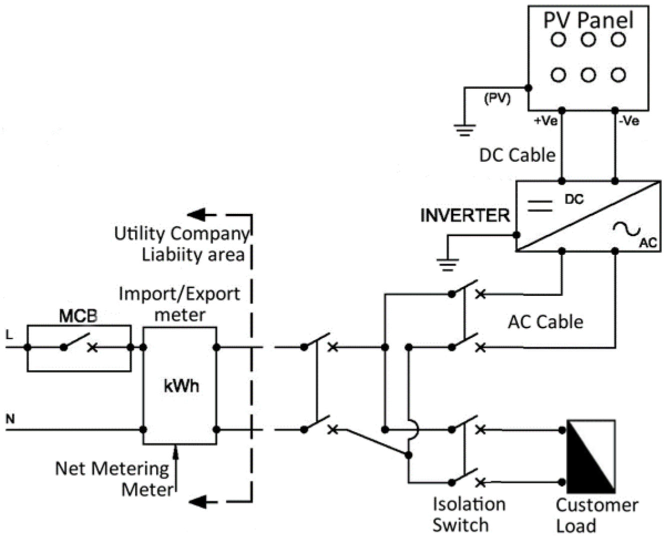


Figure 16. Connection scheme adapted in Cyprus for Net Metering.

Additionally, the net-metering consumer is obliged to pay a fixed charge based on the installed capacity of the PV system. The fixed charge is divided into the transmission and distribution (T&D) costs and the taxes and levies as shown in the Table below.

Table 5. Net-metering fixed charges, taxes and levies summary.

Description	Debit (€/kWp)	Credit (€/kWp)
Operating expenses of Transmission System Operator (TSO-Cyprus)	1.48	
Ancillary Services	3.50	
Support of system for continuous supply of demand	13.82	
Charge for tertiary reserve	1.53	
Transmission Use of System Charge	3.98	
Distribution Use of System Charge – Medium Voltage	12.31	
Distribution Use of System Charge – Low Voltage	20.41	
Reduction due to less grid losses		20.00
Total amount for CERA's decision 909/2013 (Total=Debit-Credit)[1]	37.03	
Public Support Fund	2.19	
RES fund	8.05	
Total amount per year (Total=Debit-Credit)	**47.27**	

[1] – CERA's decision 909/2013 can be found in the web site of CERA: www.cera.org.cy

2.8 Promotion of PV energy through net metering optimization PV-NET project [5](FOSS Coordinator)

The project, "Promotion of PV energy through net metering optimization" (PV-NET), that aimed at developing better energy policy for the promotion of renewable energies in the Mediterranean countries, targeting the best and most cost efficient use of PV technology. The focus was on the optimization of smart energy management systems in order to create alternative economic and sustainable measures through harmonization and reassessment of existing support schemes including government subsidies and grants. The project was completed at the end of June 2015.

PVNET provided recommendations for possible net-metering policy adjustments in the Mediterranean region. The ultimate goal was to provide policy makers with the necessary inside view of net-metering calculations, which will aid them in fine-tuning the net-metering policy in order to create a win-win situation for both investors and grid operators.

The project has given evidence that a possible solution to revitalize the market away from FiTs is the Net-Metering scheme. As was evident through the work of the project, this policy targets prosumers, i.e. those who at same time produce and consume energy. To a large extend, the main target is small residential installations. Under Net-Metering, the prosumer offsets the energy produced by the PV installation with the energy consumed by own installation, which happens generally at different times i.e. the utility acts as an energy storage. In case the produced energy is lower than the energy consumed, then the prosumer may either be charged only for the "net" energy consumed (consumed-produced energy), which is the ideal case and is characterized as "full-netting", or charged additionally for using the transmission and distribution grid and other grid services, a case where policies can vary significantly. On the other hand, when the energy produced is higher, policies may foresee the injection of the excess energy to be compensated at various prices, or not being reimbursed to the prosumer at all. Questions that arise regarding a Net- Metering scheme as a policy driver may be the price of utility reimbursement for the excess energy, the adoption of full or partial netting, possible extra charges posed by the utilities to account for the grid services etc. From the prosumer side, interest is focused on the optimal PV system size for a certain Net-Metering scheme according to the range of consumption in order to make such an investment attractive.

As in many RES technologies, a net-metering policy is viable only if adapted to the special characteristics of a country`s energy market. At the present time, a general EU policy is absent. This situation is worsened by the fact that net-metering is a relatively new concept in the RES community. More research and trial applications are needed in order not only to fully assess the techno-economic benefits of net-metering but to define net-metering as a promising alternative to FiT schemes. Currently, the countries that have adopted net-metering policies are Belgium, Cyprus, Denmark, Hungary, Latvia, the Netherlands, Romania, Israel and Turkey, with Greece and Portugal being the latest additions. In Cyprus, net-metering is relatively new, grid costs are included and the netting is done bi-monthly.

Several policy variations exist and these were investigated. The main parameters that can be modified in order to formulate different scenarios are:

- Full netting: Under a full netting scenario, the prosumer is charged based on the existing electricity tariff, only for the net energy consumed (net=produced - consumed);
- Partial netting: Under partial netting, the prosumer is charged for the net energy consumed for certain charge categories (usually the production cost charges), but not all. The prosumer may be charged in other charge categories

(network cost, taxes etc) based on either the total consumption or the incoming energy;

- Netting period: An important parameter that relates to the time period during which the "netting" is calculated and afterwards any excess PV produced energy is reset.

Billing period: The period during which the netting is performed and the consumer is charged according the existing policy. Excess PV energy may be transferred to the next billing period or sold back to the grid at certain price.

Excess energy: At certain cases, the amount of PV energy produced is higher than the energy consumed at a certain billing period. The excess energy maybe transferred to the next billing period (usually up to 1 year) as Renewable Energy Credits (REC), sold back to the grid at certain price, or given to the grid for free.

2.9 Smart net metering for promotion and cost-efficient grid-integration of PV technology in Cyprus SmartPV project [6] (FOSS Coordinator, EAC partner)

The Project "Smart net metering for promotion and cost-efficient grid-integration of PV technology in Cyprus" with the acronym SmartPV, is co-financed by the EU through the LIFE+ Programme. This Project is in line with the general and specific objectives of LIFE+ Environment, Policy, and Governance particularly as regards to contribution in implementation, updating and developing environmental policy. The SmartPV project thoroughly investigates pilot net metering schemes for cost-effective PV implementation and higher grid penetration in Cyprus of distributed generation with the target of achieving a WIN-WIN scenario for both consumers and energy utilities. The project is expected to hand over all deliverables within 2017.
SmartPV aims to develop a simple energy policy scheme for higher renewable energy source (RES) penetration in the energy mix of Cyprus, based on the concepts of smart net metering and self-consumption. The specific target is to achieve optimum implementation of PV technology in terms of cost and efficiency. SmartPV focuses on the optimization of net metering system schemes as a financial and viable alternative to expensive and unnecessary governmental subsidies and grants for PV
Through the implementation of the project SmartPV, the net metering schemes will be optimized for the particular case of Cyprus, taking into account local conditions and strategies for energy pricing. The project will aim to highlight and understand the impact of smart net metering implementation on consumer billing options, consumption sensitivities, consumer energy-related behaviours, and cost and benefit implications for network owners and operators in Cyprus (financial impact). Furthermore, it is important to persuade the consumers on sustainability and the economic benefit resulting from the adoption of PV Net metering, which nowadays is very important due to the high cost of electricity.
The project foresees the pilot implementation of net metering systems for PV in a wide range of areas in Cyprus essentially providing a credible sample to represent the situation in the whole of Cyprus. For this purpose, the energy consumption and production of about 300 prosumer pilot sites in Cyprus are being examined. The aim of the pilot demonstrations is to assist in the development of the most optimum PV net metering model via the analysis of real data generated by the pilot plants. Data on consumption and tariffs will be selected and therefore will be studied and compared. The data series that will be collected will be used to optimize the model, which will be customized for the case of Cyprus. Thus, the pilots will be used to demonstrate and prove the benefits of PV net metering by validating different models. Furthermore, investigations will also take place in terms of the environmental impact, with a focus on CO2 emissions reduction, as well as of the socio-economic impact of the implementation of net metering policies for PV promotion in Cyprus.
During the first part of the project the focus has been mainly on the implementation of the pilot sites to enable reliable data to be collected, which, subsequently will be used for the development of the net metering models, the optimization of the different tariffs and the implementation of demand side management through active prosumer participation.
More analytically the following activities have been initiated and significant progress has been made:

- Development of the protocol for the selection of the pilot sites
- Approval for dynamic tariff use (preliminary approval has been granted by the Electricity Authority of Cyprus-EAC and the Cyprus Energy Regulatory Authority-CERA)
- The base case scenario has been completed
- Design of the smart metering, meteorological and data acquisition solutions

(this includes the meters, meteorological stations, data acquisition and direct link between EAC and the University of Cyprus (UCY)

- Policy analyses and dynamic tariff model development based on current international practices
- Dynamic model development
- Socio-economic impact
- Communication and Dissemination
- Networking

2.10 Green+ (EAC Coordinator, FOSS Partner)

The project entitled Green+ is a successful proposal project under NER300 call and it falls under category of Renewable energy management and optimization for small and medium scale Distributed Generators in rural environment with predominant solar generation: 20MWe on Low Voltage (LV) network + 50 MWe on Medium Voltage (MV) network. The project will cover all technologies to develop a multi-microgrid system with 20 MWhrs of storage for facilitating RES penetration to meet the energy needs of the rural areas of Cyprus. The award decision was taken in July 2014 and the project is still at the planning stage.

The rural mountains, and densely forested areas and regions in Cyprus face increasing challenges while trying to maintain a balance between reliable electricity supply and minimal impact on the sensitive local environment. Indeed, the erection of transmission overhead lines and substations has been effectively brought to a halt in this area due to both protests from local communities as well as restrictions imposed by the Department of Forestry which seeks to maintain a minimum level of interference to the local environment from the ever increasing installations of lines and electricity distribution equipment. As a result, the Electricity Authority of Cyprus seems to be running out of options when it comes to network reinforcements and particularly additional installations necessary to keep up with the increasing demand for electricity especially during the holiday season when these areas are populated.

The proposed project seeks to radically address and give solutions to the problems mentioned above and hence promote sustainable growth in the area in addition to the much needed local economy boost.

The project proposed considers that in the mountainous area of Cyprus, outlined on the accompanied Project's Geographical Area of deployment map, in the coming years, renewable energy installations will rapidly grow, by taking into account the following facts:

- There are tens of projects at licensing phase for wind and PV generation.
- In Cyprus, net metering on electrical energy is already applied in a pilot project and a next phase will be announced shortly for another 5.000 homes. There is also a scheme underway for approval for a further expansion of the scheme.
- There are existing applications at the Cyprus Energy Regulatory Authority for more than 100 MWp of self-generation from Photovoltaics in self-supporting their industrial and commercial energy needs.

To manage effectively the aforementioned developments in local generation, EAC is planning the establishment of a micro-grid type of architecture in the affected region. The proposal consists of the following particulars:

- The promotion and incentive based installation of 30 MW of photovoltaic systems on local house roofs (4kW on each roof, starting at 3 kW for the first 5000), and facilitate the installation of commercial photovoltaic and wind generation.
- The installation of 20 MWh energy storage systems at distribution level, mainly in transmission substations and also close to large local renewable generation sites.
- Mass deployment of smart meters in all domestic and commercial establishments that fall within the Project's Geographical Area of deployment which will effectively embed intelligence and offer data collection capabilities.
- Adoption of Active Demand Load Management technology through the use of dynamic tariffs for peak demand shave off.

- Adoption of new electricity tariffs that will promote passive Demand Load Management.
- Utilization and installation of smart grid control architecture at distribution level in the Green+ PGA.
- Deployment of necessary communication means for the operation of smart grid and microgrid infrastructures to be created within the PGA.

All the above are expected to gradually lead to optimal use of energy sources with minimal need for energy import from sources external to the PGA and hence negate or minimize the need for erection of additional distribution and transmission network facilities. Through optimal use of local generation, local distributed storage and demand side management, the targeted area will be gradually operated as a coordinated Distribution Management System through a hierarchical microgrid infrastructure and hence will maximize the benefits to the participants in the targeted area. The distributed generation and storage to be used will depend on strict cost and benefit analysis backed up by supply from the interconnected system. This will gradually change as technologies are made available for further investments in the area that will further enhance the rewards to the participants.

It is widely known that distributed generation imposes great challenges on operation parameters, such as voltage, frequency, and other power quality parameters, that must be kept within pre-defined limits in order to continuously maintain a certain level of power quality delivery for all consumers connected to the distribution network. This is due the fact that today's distribution networks are designed, operated, and protected on the premise of there being a single source on each distribution feeder.

However, the main constrain of the existing network capability is the Voltage stability. The introduction of 80 MWe power from renewable energy sources (30 MWe on the Low Voltage Network and 50 MWp on the Medium Voltage Network) will have the tendency to increase the voltage level depending on the production of energy from these sources. The existing network at this moment has no ability to deal with reverse power flows since there is no means of predicting the excess energy generation and the load in the area. The existing network was designed and operated as a single direction network and the introduction of distributed generation in the area will also create energy management problems besides increasing voltage levels.

DG can be connected to the grid directly using synchronous or induction generators or through a power electronic interface. Synchronous generators or power electronic interfaced DG can be operated at various modes of the reactive power. The DG either generates or absorbs reactive power or the DG does not exchange reactive power with the distribution system. Synchronous generators or power electronic interface based DG can also be involved in the distribution system voltage control, i.e., when the DG is operated at a constant voltage by varying its reactive power output. On the other hand, induction generator based DG always absorbs reactive power.

For a system with load and DG as shown in the Figure below, the voltage drop on the feeder can be approximated by:

$$\Delta U = U_1 - U_2 \approx \frac{R_{LN}(P_L - P_{DG}) + X_{LN}\left(Q_L - (\pm Q_{DG})\right)}{U_2} \qquad (2)$$

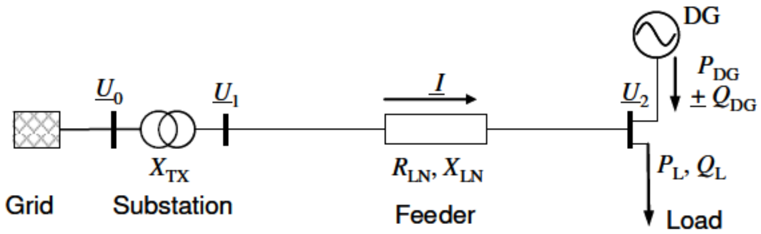


Figure 17. Example of system with load and DG.

This indicates that if the DG generates reactive power or the DG does not exchange reactive power with the grid, the DG will always decrease the voltage drop along the feeder. If the generated power is larger than the feeder load, power will flow from the DG to the substation and causes a voltage rise.

Further, the above equation indicates that, if the DG absorbs reactive power, the DG can either increase or decrease the voltage drop. This depends on the DG active and reactive power relative to the load active and reactive power and the X/R ratio of the line.

Another constraint of the existing network is the length of Medium Voltage Overhead lines, located in rural areas. These are prone to weather conditions especially storms and lightning. Fault location is very difficult and time consuming thus affecting the Quality of supply to consumers. These long duration fault clearing times will inevitably isolate renewable energy sources for long periods of time.

The introduction of the AMI system with smart meters, sensors, weather prediction stations together with the Distributed Renewable Management System will enhance the ability of the network to locally predict the renewable generation and the load, therefore allowing the network to manage forward and reverse power flows. The introduction of self-healing to the proposed network will reduce outage and fault clearing times to the benefit of consumers, prosumers and renewable energy producers thus providing better Quality of supply.

The DRM System facilitates integration of distributed renewable energy by monitoring and balancing the local generation and demand so that optimally no curtailment of renewable generation or demand is necessary to satisfy minimum electrical operational requirements. To this end, the PGA will be treated as an autonomous power system seen as a hierarchically organized grid, consisted of gradual levels of microgrids. Monitoring of relevant data acquired from smart equipment, such as smart meters, sensors and weather stations will be integrated in local and central controllers to add smartness and conduct knowledge based decisions by the network's control. Pro-active and post-active logic will take advantage of this extended knowledge of the network's status to come to optimum decisions regarding its operation. An important added-value function of the DRM is the ability of each microgrid to operate independently, even when there is an outage to the feeding network, minimizing the renewable energy loss.

A core function of the DRM System, besides hierarchical control, will be energy storage that will be installed to back up the system mostly when renewable energy is not adequate for the area's energy demand, resulting in an almost autonomous and unconstrained operation, with minimum electrical losses since energy will be generated, stored and consumed locally. Over-production, i.e. when renewable generation exceeds local demand, will be stored for later use and mitigate the effects of redundant renewable energy of the grid which would either wise impose over-voltages on the grid. Vice versa, under-production, i.e. when renewable energy is short compared to local demand, stored energy will be utilized as flexible capacity to avoid import of energy from the rest of the power system, and thus avoid unnecessary commitment of conventional generators with higher cost, transmission network losses,

and central peak-load power plants from contributing to this shortage in an inefficient and costly manner.
The network's capability to accommodate DG will be further increased since the future DRM System entails the following functions:

- Automated Voltage and VAR control: Automated voltage and VAR control shall be operational at Low and Medium Voltage. Automated voltage and VAR control requires coordinated operation of reactive power resources such as capacitor banks, voltage regulators, transformer load-tap changers and inverters at distributed generation with sensors, controls, and communications systems. These devices could operate autonomously in response to local events or in response to signals from a central control system.
- Automated Frequency and W control: Automated Frequency and W control shall be operational mainly at Medium Voltage level. Some load (W) control shall be implemented via the AMI and smart meters on household, commercial and industrial installations. Automated Frequency and W control requires coordinated operation of real power resources such as photovoltaic systems, storage and load management through the smart meters and Medium Voltage circuit breakers and autoreclosers. These devices could operate autonomously in response to local events or in response to signals from a central control system.
- Weather Forecasting: Wide area monitoring and visualization requires time synchronized sensors, communications, and information processing that allows the condition of the bulk power system to be observed and understood in real-time so that action can be taken. Weather forecasting data in several locations are vital for real-time prediction of demand and RES generation in order to take immediate action to keep a balanced and stable system at all times.
- Demand/RES generation prediction: Weather, smart meter, photovoltaic systems and storage data should be gathered in order to automatically produce the demand and RES generation profiles prediction and timely organize operations in order to achieve balance at all times.
- Real Time Load Measurement and Management: This function provides real-time measurement of prosumers consumption and management of load through Advanced Metering Infrastructure (AMI) systems (smart meters, two-way communications) and embedded appliance controllers that will help customers make informed energy use decisions via real-time price signals, time-of-use (TOU) tariffs and service options, in conjunction with the benefits of passive and active demand side management actions of the utility.
- Utility Network Optimization: Flow control and the data of the network should allow through Automated Feeder switching to minimize losses and allow for better network utilization.
- Automated Feeder Switching: Automated feeder switching is realized through automatic isolation and reconfiguration of faulted segments of distribution feeders via sensors, controls, switches and communications systems. These

devices can operate autonomously in response to local events or in response to signals from a central control system.

- Adaptive Protection: Adaptive protection uses adjustable protective relay settings (e.g., current, voltage, feeders, and equipment) in real time based on signals from local sensors or a central control system. This is particularly useful for feeder transfers and two-way power flow issues associated with high DER penetration.
- Diagnostics and Notification of Equipment Condition: Diagnosis and notification of equipment condition is defined as on-line monitoring and analysis of equipment, its performance and operating environment to detect abnormal conditions (e.g., high number of equipment operations, temperature, or vibration). Automatically notifies asset managers and operators to respond to conditions that increase the probability of equipment failure.
- Enhanced Fault Protection: Enhanced fault protection requires higher precision and greater discrimination of fault location and type with coordinated measurement among multiple devices. For distribution applications, these systems will detect and isolate faults without full power re-closing, reducing the frequency of through-fault currents. Using high resolution sensors and fault signatures, these systems can better detect high impedance faults. For Medium Voltage Network applications, these systems will employ high speed communications between multiple elements (e.g., primary stations & Transmission Substations) to protect entire regions, rather than just single elements. They will also use the latest digital techniques to advance beyond conventional impedance relaying.
- Automated Self-Healing Switching: Through the Enhanced Fault Detection automated self-healing shall be operational on Medium Voltage network. Through Automated Feeder Switching, the faulted section shall be isolated and power to be re-instated through the rest of the network.
- Real time Control and Operation of Battery Storage: Remote utility control of electricity storage inflow/outflow reduces energy costs and enhances power generation and T&D capacity utilization.
- Customer electricity use Optimization: Customer electricity use optimization is possible if customers are provided with information to make educated decisions about their electricity use. Customers should be able to optimize toward multiple goals such as cost, reliability, convenience, and environmental impact. For this proposal, the prosumers will be provided with in- house displays for real time information of the production of the photovoltaic system and their load demand profile in order for the utility to passively control energy consumption. In the future, active load management within the household will be enabled with smart household appliances.
- Improved utilization of power plants: Passive demand side management shall be possible by applying dynamic pricing and active demand by remotely and

directly acting on consumers smart appliances or network segments to curtail instant demand.

- Cleaner transport: The DRM shall on the long-term facilitate Electric Vehicle (EV) and Plug-in Hybrid EV integration as well as Vehicle-to-Grid (V2G) function to support the grid when necessary.

Through the above mentioned functions the DRM will enhance the network's capability to accommodate the Distributed Generation within the PGA and through the following mechanisms summarized in the Table below, in order to achieve lower carbon than the traditional approaches.

Table 6. GHG emission mechanisms enabled by Smart Grids.

GHG emission reduction	Mechanism
End-use efficiency improvement	Energy saving effects of consumer information and feedback
Facility efficiency improvement	Fine-tuning of air-conditioning, lighting systems etc.
Improved utilization of power plants	Demand response from dynamic pricing and load curtailment
Cleaner transport	Facilitation of EV and Plug-in Hybrid EV (PHEV) deployment
Integration of distributed renewable energy	Facilitating bi-directional power flow, voltage and frequency control on Medium and Low Voltage networks

Additionally, the Table below indicates the Characteristics of the Conventional grid against those of Smart Grids.

Table 7. Smart Grid versus Conventional Grid Characteristics.

Characteristic	Conventional Grid	Smart Grid
Consumer participation	Consumers are under-informed and non-participative with power system.	Informed, involved and active consumers – demand response and distributed energy resources.
Integrating generation and storage	Dominated by central generation. Many obstacles exist for integrating distributed energy resources.	Many distributed energy resources with plug-and-play convenience, focusing on renewables.
Market evolution	Limited wholesale markets, not well integrated. Limited opportunities for consumers.	Mature, well-integrated wholesale markets, growth for new electricity markets for prosumers.
Power quality	Focus on outage and slow response to power quality issues.	Power quality is priority with variety of power quality/price options – rapid resolution of issues.
Asset optimization	Little integration of operational data with asset management-business process silos.	Greatly expanded data acquisition of grid parameters – focusing on prevention, minimizing impact on prosumers.
Responsiveness	Responds to prevent further damage-focusing on protecting assets following fault.	Automatically detects and response to problems - focusing on prevention, minimizing impact on prosumers.
Resiliency	Vulnerable to natural disasters and malicious acts of terror.	Resilient to attacks and natural disasters with rapid restoration capabilities.

The following Figures show the reference area of the Green+ project. More specifically the Figure below shows the reference area per communities while the second one shows the reference area with the MV network.

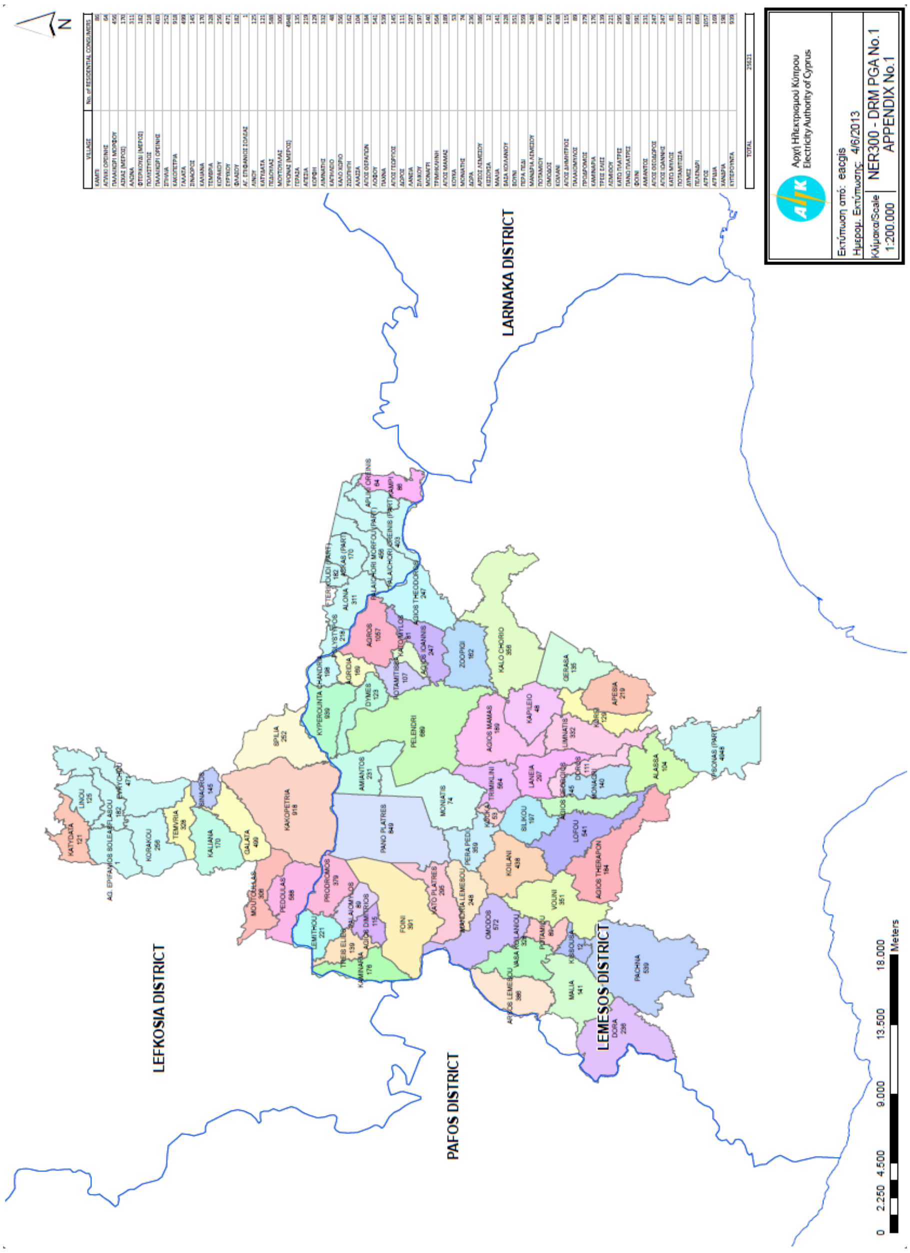


Figure 18. Reference area of the Green+ project per communities.

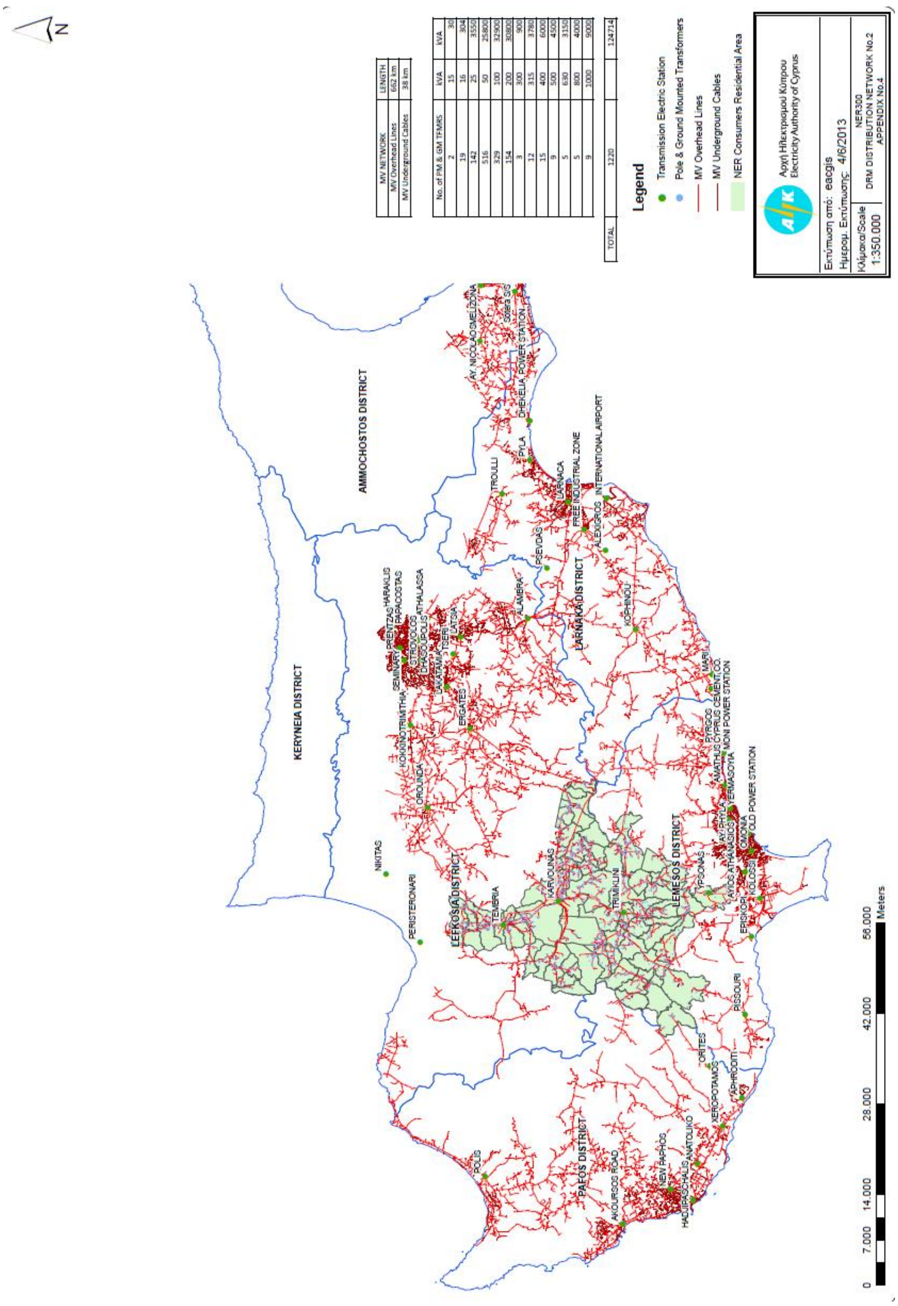


Figure 19. Reference area of the Green+ project with the MV network.

3. Conclusions

In this report information about completed, ongoing and planned Smart Grid projects in Cyprus is presented along with a mapping of related technical issues they address (please refer to Table 9 below). The projects that are included cover all the work involving smart grid solutions that the EAC of Cyprus has been involved in till today and they include projects that have been completed, are in progress or are planned / approved to go ahead shortly.

Table 8. Mapping of projects in Cyprus with deployed or planned to be deployed smart grid technologies.

Project Title	Smart Grid Technologies
Geographic Information System (GIS)	Spatial information with real time electrical connectivity of all active grid components
Virtual Power Plant	Smart meters, smart controllers, Central Management System, GPRS communication
Charging Infrastructure for Electric Vehicles	Smart meters, , GPRS communication, EV charging stations based on open charge point protocol (OCPP) system, EVs smart management system
Smart inverters with distributed control	Smart inverters,
Advanced Metering Infrastructure	Smart meters, Concentrators, MDMS management system, PLC and GPRS communication infrastructure, In House Displays with smart meter connectivity
SCADA Distribution	Open architecture interface with Transmission SCADA, external systems such as AMI, VPP, EVs central management system etc, Smart Data Management System
Net Metering in Cyprus	Smart meters, GPRS communication, Meter Management System
PV-NET	Smart meters, GPRS communication, Meter Management System
SmartPV	Smart meters, GPRS communication, Meter Management System
Green+	Smart meters, GPRS communication, PLC communication, MDMS, Microgrid fast switch, Storage systems, In House Displays, EVs Smart Charging Infrastructure, Concentrators, Smart Controllers, Distribution Management System, Microgrid Central Controller, Microgrid Controller, Smart Data Management System

The report reflects the work of the EAC in the following important areas:

- **Geographic Information System (GIS)** (EAC)**:** The platform that is being developed is a combination of ArcGIS of ESRI and Schneider Electric's ArcFM that runs on top of ArcGIS to give to the overall system desirable electrical attributes.

- **Virtual power Plant (VPP)** (EAC)**:** Virtual Power Plant developed by the EAC transforming private generators of sizes ranging from around 400 kVA to 1500 kVA that is currently operational through a centralised system available at the EAC SCADA control centre, offering a cold reserve approaching 40 MVA in steps varying from 1 MVA to 39.45 MVA (64 generators in total). This is the maximum available capacity and the DSO / TSOC have the option to modify the steps to values that suit the operational needs of the system.
- **Charging infrastructure for Electric Vehicles** (EAC)**:** Electric Vehicle infrastructure for public charging has already been developed offering 16 public charging stations throughout Cyprus. The system is fully aligned with the EU directive on the deployment of alternative fuels infrastructure 2013/0012 (COD) and the standardisation mandate to CEN, CENELEC and ETSI concerning the charging of electric vehicles M/468. The project is fully operational fulfilling the needs of EV users in Cyprus. The infrastructure deployed is based on the international standard IEC 61851 covering modes of charging, cables and terminal points.
- **Smart inverters with distributed control** (EAC)**:** The Grid Rules of Cyprus [1] are obligatory to all users of the grid and have adapted all the requirements of the European Standard EN 50160. In addition to what is included in the standard, RES generators are expected to operate their systems in accordance with the requirements of Chapter 16 of the T&D Grid Rules of Cyprus and the additional technical terms issued by the DSO to all prospective RES generators. These important technical solutions maximising the use of smart inverters in support of RES penetration are well covered in the "Final report for Task 3.1.2, Analysis of distribution grid control techniques" section 5.1 [7].
- **Advanced Metering Infrastructure (AMI)** (EAC)**:** The Advanced Metering Infrastructure (AMI) project that is tendered out by the EAC covering two distinct sections of the grid for implementing all the possible technologies (smart meters, concentrators, MDMS management system, fibre optic, PLC and GPRS communication infrastructure, in house displays in full communication with the provided smart meters, integration of the provided systems with the billing and management IT solutions of the EAC etc).
- **SCADA Distribution** (EAC)**:** The EAC of Cyprus is planning with the support of an external advisor, a complete SCADA / DMS (Distribution Management System) which includes a set of modules that will provide the EAC the necessary tools for the complete management of the network, both for daily work and under faulty conditions.
- **Net-Metering in Cyprus** (Electricity Authority of Cyprus): The net-metering policy in Cyprus concerns only residential consumers and the PV system is currently limited to 3 kWp of installed capacity. The policy allows the consumer to import energy from the grid when the production of the PV system is

insufficient, to export energy to the grid when the energy yield is surplus and to self-consume energy directly from the PV system.

- **PVNET** (FOSS Coordinator)**:** The project, "Promotion of PV energy through net metering optimization" (PV-NET), that aimed at developing better energy policy for the promotion of renewable energies in the Mediterranean countries, targeting the best and most cost efficient use of PV technology.
- **SmartPV** (FOSS Coordinator, EAC partner)**:** The Project "Smart net metering for promotion and cost-efficient grid-integration of PV technology in Cyprus" with the acronym SmartPV, thoroughly investigates pilot net metering schemes for cost-effective PV implementation and higher grid penetration in Cyprus of distributed generation with the target of achieving a WIN-WIN scenario for both consumers and energy utilities.
- **Green+** (EAC Coordinator, FOSS Partner)**:** The project entitled Green+ covers all technologies to develop a multi-microgrid system with 20 MWhrs of storage for facilitating RES penetration to meet the energy needs of the rural areas of Cyprus.

4. References

[1] Dieter Gutschow, Daniel Bohm, John Dimitropolous, Gisele Widdershoven of KEMA Nederland B.V., " Advanced Metering Infrastructure Pilot System Policy and Strategy for EAC" *February 2011*

[2] TSO of Cyprus "Transmission and Distribution Rules of Cyprus", *Issue 4.0.0, July 2013, www.dsm.org.cy*.

[3] www.eac.com.cy, Web page for Electricity Authority of Cyprus

[4] www.cera.org.cy, Web page for Cyprus Energy Regulatory Authority

[5] www.pvnetmetering.eu/, is the web page of the PV-NET Med project

[6] www.smartpvproject.eu, is the web page of the SmartPV Life+ project

[7] FOSS in relation to the project "Analysis of the Present and Future Power Distribution System in Cyprus JRC/PTT/2015/F.3/0019/NC", Final report for Task 3.1.2 "Analysis of distribution grid control techniques"