MAKING MODERN LIVING POSSIBLE

Medium to large scale solutions
based on TLX Pro

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Preface

PV systems ranging from several 100 kVA and up require a detailed system design to provide an optimum solution. With TLX Pro string inverters there is no need to compromise on system performance. The flexibility of the inverters enables optimal system planning even of very large systems by anyone possessing a standard understanding of PV systems.
All requirements from the distributed network operator (DNO), such as power level adjustment or reactive power exchange, are fulfilled. The PV systems can be connected directly to the LV grid, or to the MV grid by using a standard MV transformer. With integrated monitoring and communication functions external devices are only required for certain grid management purposes. Master functionality means that data warehouse services can easily be utilised if desired.

TLX inverters provide the ideal solution for any PV system, free of extra cost or compromise.

Summary

This paper is a part of a series whose purpose is to enable system designers to benefit from Danfoss' system knowledge. The knowledge collected in the papers, along with the inherent flexibility of the TLX inverters, will enable system designers to utilise TLX Pro inverters in different applications ranging from residential installations to large commercial power plants. The papers outline how PV Systems are optimally designed using the high efficiency TLX Pro string inverters, and how these inverters contribute to the simplification of system communication, commissioning and service.

This particular paper describes installations with multiple TLX inverters of a total grid connection rating ranging from 100 kVA to more than 1 MVA, with the limit set at 100 inverters connected together.
Interconnecting systems of 100 inverters to form larger systems is possible but you must be aware that DNO or technical limits may come into play. You should therefore contact Danfoss in order for us to help you find the best solution for your large MW installation.

Using TLX inverters you are able to design a medium to large scale commercial PV system for every roof top or ground size without special expertise in central inverter solutions. For this system size, several rooftop areas are usually required, and the area is often subjected to partial shade. The design of the PV system is simplified significantly by using small inverter units with a high number of MPPTs.
Ground based systems are usually very large, and require extra mounting equipment. TLX inverters with their inherent high ratio of MPPTs allow you to accept shading situations during the winter months. This means that the rows may be placed closer together, providing better utilisation of the area available. Additionally, surface space related costs for e.g. cabling, m2 rents, etc are also reduced due to the compact dimensions.
With a three-phase output on the AC side, and the very high maximum DC voltage, the user is provided with a high degree of flexibility in selecting the ideal inverter mounting location. Long cable runs can be installed on both the DC and on the AC sides without high cable losses.
The MV transformer station, required for MV grid connection can be a standard station. These are usually reasonably priced and easily available. Due to the high number of independently working inverters, the system will only be limited affected even if you experience partial failure of modules or inverters.

A detailed monitoring of module strings is possible without additional hardware. The high number of multiple power point trackers (MPPT) combined with the high efficiency of the trackers allow for the best possible yield for every kind of roof, even with shading. The combination of several 15 kVA inverters with other TLX inverters of different power ranges makes it possible to select a total AC output power with the ideal ratio for PV power.

A data logging, monitoring and control system is integrated into the TLX Pro inverter. External sensors for temperature and irradiation can be connected directly to a master inverter, enabling easy integration of the reference performance monitoring. For systems requiring power level adjustment (PLA) or other ancillary features associated with systems connected to medium voltage (MV) networks, a Grid Management Box is used to relay the input from the distributed network operator (DNO) into the system. The master inverter will then ensure the system performs according to DNO requirements. Thus a system based on TLX Pro comprises a complete verified system from a single manufacturer.

Any TLX Pro inverter can be set up as system master, and ordering a special unit is thus not necessary. The other inverters in the system can be connected to the master via Ethernet LAN in star or daisy chain configuration according to installer's preference. Once connected, the IP address will be set up automatically. Installers can also use the inverter's built-in web interface to simplify installation, which includes parameter settings required for PLA or auxiliary features for the MV network. Via the master inverter it is possible to replicate the setup parameters to every inverter in the plant. Thus communication cabling and system setup is simplified, which reduces installation time and the potential for errors.

Unlike central inverters, special training is not required to be able to install, maintain or exchange string inverters. The local electrician can maintain the string inverter installation, meaning that service contracts requiring specialists from the inverter manufacturer are not required. For service purposes, backup of settings and data is available in the inverter display enabling a quick exchange. Furthermore, by omitting junction boxes, no service on the DC side is required.

For monitoring you can use the built-in Web server interface, for easy overview of the installation, or the master inverter can be set up to automatically send data to data warehouse services, using its built-in FTP upload feature. Through the web interface of the data warehouse provider, it is possible to carry out standard plant monitoring down to detailed error analysis. Data down to individual string level is transferred for central storage and monitoring of long term effects.

Introduction

In a PV system the inverter links the DC based PV panels to the AC based grid with the purpose of transferring as much power as possible from the modules to the grid. To be successful in this task the inverter must both draw out as much energy from the modules as possible and feed in as much energy as possible.

In the following sections we will address how you can ensure that both the PV and grid side of your plant is optimised from the point of view of the inverter.
To ensure maximum operation time and minimised down time a monitoring system is recommended. Depending on preferences different solutions may be considered, a selection of solutions is therefore presented.
How the inverter is installed may also influence the system so this is also addressed.
Finally we will briefly mention considerations regarding service of the inverter.

2.

Photovoltaic panels and DC configuration

How much of the sun's energy you can harvest will depend on the type of module and where and how they are installed. Panels are available of different types and sizes, which lead to many different combinations of PV configurations being possible. Selecting the optimal configuration to match the local installation conditions thus becomes relevant in order for the inverter to optimise the amount of PV power for conversion into AC power.

In order to give you the widest possible range of solutions we have given the TLX inverters the following characteristic:

- 4 power sizes (8 kVA, 10 kVA, 12.5 kVA, 15 kVA)
- 2-3 individually regulated MPP Trackers of each:
  - 1000 V_{DC} open circuit
  - 250-800 V MPP range
  - 12 A input current

Selecting the PV panels is one of the first tasks to be performed.

2.1 Monocrystalline panels or Polycrystalline panels

Two types of crystalline standard solar cells are available: the less expensive polycrystalline cells and the monocrystalline cells with slightly higher efficiency. A vast majority of polycrystalline cells are produced in 6.inch units (156 mm × 156 mm) with a maximum power of 4 Wp. Standard monocrystalline cells are available in 5-inch units (125 mm × 125 mm) with up to 2.8 Wp, or in 6-inch units with up to 4.2 Wp. New efficiency records for mass production solar cells were recently published, though these cells are not yet widely available.

2.1.1 Standard polycrystalline panels

The most common application of polycrystalline cells are modules with 48, 54 or 60 cells. There are also large, 72-cell modules on the market, though these are less common. According to the cell power these modules yield up to 190 Wp (48 cells), 215 Wp (54 cells), 240 Wp (60 cells) or 290 Wp (72cells). The DC input parameters of the TLX inverters are optimised to connect one string of these modules to one input with its own MPPT.

2.1.2 Standard monocrystalline panels

Modules with 6-inch monocrystalline cells are increasingly available on the market. These are available with the same number of cells per module as those mentioned above with polycrystalline panels. The power values of monocrystalline panels can reach up to 200 Wp (46 cells), 225 Wp (54 cells) 250 Wp (60 cells) or 300 Wp (72 cells). Here it is also the most useful to connect one string to one input with its own MPPT.
Five-inch units are primarily used in modules with 72 or 96 cells. These modules yield up to 200 Wp (72 cells) or 270 Wp (96 cells). The maximum possible power per string compatible with the TLX inverters amounts to 3.8 kWp. The installer must therefore connect a higher number of strings to the inverters to obtain the usual layout factor, when compared to modules with 6-inch cells; e.g. five stings to a TLX 15k.

2.2 Thin film panels

All thin film panels that do not require grounding on the DC side are compatible with TLX inverters. Modules based on CIS or CIGS technology, in particular, are used for residential PV systems and can also be used with transformer-less inverters. One important challenge brought about by using thin film panels is the high module voltage. This reduces the maximum number of modules per string; hence, the maximum power per string is limited to around 1.5 kWp. Often less than 1 kWp power per string can be reached with thin film panels. This means that the installer must connect a greater number of parallel strings to obtain the recommended PV power of any inverter. Here the multiple MPPT of the TLX inverters come into play. With three to eight strings per DC input/MPPT in many cases, it is not necessary to use string diodes or string fuses. This reduces the installation costs and eliminates additional potential for error.
Having chosen the panels, the configuration of strings to utilise the area available and accommodate for the installation location is of importance.

2.3 Layout factor

A plant which utilises power via high-efficiency inverters located in Central Europe should not exceed a layout factor of Psolar/Pinverter = 1.12, as indicated by Dr Bruno Burger[1].
Due to better Pmpp temperature coefficients and a better low light performance for thin film modules, it is advisable to use a lower layout factor of maximum 1.1 for thin film modules.

[1] Inverter sizing for grid connected PV plants: Dr.-Ing. Bruno Burger, Fraunhofer-Institut für Solare Energiesysteme ISE Heidenhofstraße 2, D-79110 Freiburg.

For crystalline modules with standard solar cells, different options are available with the TLX 15k at optimal orientation:
Standard Crystalline modules with 6-inch solar cells:

- 1 string of up to 24 modules with 60 cells on each of the three inputs
- 1 string of up to 26 modules with 54 cells on each of the three inputs
- 1 string of up to 30 modules with 48 cells on each of the three inputs

Standard Crystalline modules with 5-inch solar cells:

- 5 strings of up to 20 modules with 72 cells divided on the three inputs
- 5 strings of up to 15 modules with 96 cells divided on the three inputs

Thin film modules as examples First Solar FS-377 and FS-277:

- 14 strings of 15 modules FS-377 divided on the three inputs
- 21 strings of 10 modules FS-277 divided on the three inputs

The farther away from optimal orientation and inclination, the higher the layout factor should be. For example, a roof with a 45° inclination and a westward orientation may have a layout factor of around 1.18, because the roof will not be exposed to the sun the whole day, and the sun will have less power when it hits the roof perpendicularly. On the other hand, a roof with a 6° inclination and westward orientation should have a maximum layout factor of around 1.25, because the roof will be exposed to the sun almost the whole day, however always at an oblique angle.

Northwest	West	Southwest	South	Southeast	East	Northeast	North	Inclination°
125	125	118	118	118	125	125	125	<10
125	118	112	112	112	118	125	125	10
125	118	112	112	112	118	125	125	20
125	118	112	112	112	118	125	125	30
125	118	112	112	112	118	125	125	40
125	118	112	112	112	118	125	125	50
125	118	112	112	112	118	125	125	60
125	125	118	118	118	125	125	125	70
125	125	118	118	118	125	125	125	80
125	125	125	125	125	125	125	125	90

Table 1: *Layout factor in % relative to orientation of modules – Central Europe*

For installations in southern Europe, where a lower layout factor is recommended, power can easily be reduced by connecting fewer modules to each string when using crystalline modules or fewer strings to the inverter when using thin film modules

2.4 Maximum DC voltage and operating voltage

The negative temperature coefficient for open circuit voltage (Uoc) of solar modules has to be considered when determining the maximum number of modules per string. For Central Europe, the current practice is to calculate the maximum DC voltage at -10°C. At this temperature solar modules can theoretically reach Uoc values of up to 13% higher than Uoc at standard test conditions (STC). Although lower module temperatures can occur normally it is not necessary to take this into consideration This is due to the fact that the voltage decrease rate, at lower sun irradiation only result in around 10% lower Uoc values at a radiation of 200 W/m^2, as compared with 1000 W/m^2 radiation. Furthermore even at 200 W/m^2 there is a module temperature increase resulting in a significantly higher temperature than the ambient.

In order to determine operating voltage values under realistic conditions, these conditions have to be defined. For this reason, the NOCT was developed. NOCT stands for 'nominal operating cell temperature'. This value is also stated on the datasheet of a module and it stands for the typical cell temperature over the course of one year (for crystalline modules around 45°C).

The everyday operating DC voltage range is important for determining inverter efficiency. Unlike most single-phase inverters, highly efficient three-phase inverters reach operating voltage values near their nominal DC voltage. This means the inverters actually function with the datasheet efficiency. As a result, the following rule of thumb comes into play: to reach the best possible inverter efficiency you should aim for the maximum number of modules per string. If there is a single string with a lower number of modules and lower DC voltage level, the corresponding lower efficiency only affects a share of all modules connected to the inverter, with reduced effect on the total efficiency.

2.5 Maximum Power Point Tracker (MPPT)

It is not easy to find a spacious roof area that experiences no shading situations, where a PV system installation with one or more central inverters can be installed. You therefore often compromise between maximum use of the roof and the DC design possibilities of central inverters. This problem is further complicated when designing a PV system on several roofs with different orientations and/or inclinations. String inverters with multiple MPPTs allow for the optimum use of every roof; not only because you can build up a PV system with maximum power, but because the string MPPT brings out the best possible yield from every part of the roof. It is also possible to use different types of solar modules if this is deemed to be helpful in installing the system

For large ground mounted PV power plants, central inverter solutions are generally preferred. As a result, you must accept a poor ratio of PV power to MPPT: the higher the PV power per MPPT, the lower the tracking accuracy due to mismatched string MPP voltages between the parallel connected strings. Furthermore, the highly recommended string monitoring requires expensive additional installations.
In most cases, by using inverters with several MPPTs you can operate every string of crystalline modules with its own MPP voltage. The string MPPT also includes power data collection whereby no additional string monitoring is needed. This ultimately results in lower costs by abandoning additional monitoring hardware, and better yields due to better MPP tracking accuracy.

2.6 Cable loss

Cables in the PV plant will contribute to losses, -how much depends on the cable resistance. For equal amounts of power transferred on a wire you can reduce the losses either by choosing a cable with a larger cross section or by increasing the voltage. In general it is advisable to keep the total cable loss below 1%.

Having a module configuration with a nominal DC voltage in the 700 V range you will in most cases be utilising the 1000 V open circuit limit of the system and thus be running at the highest possible voltage. This means you can save cable costs by using a smaller cable cross section. Typically 4mm^2 can be used in most installations with up to app. 200 m total DC cable length. For installations with up to 300 m total cable length a 6 mm^2 cable will still keep the loss below 1%. With the DC voltage being significantly higher than the AC voltage it is also advisable to make the longer cable runs on the DC side as this will contribute to keeping the overall cable losses low.

2.7 Conclusion

The TLX inverter offers a large degree of flexibility in PV layout design, due to the strengths of 1000 V_{DC}, 2-3 independently regulated MPP trackers and 2-3 DC inputs. All crystalline panels can be connected to the inverter, thinfilm panels may be used and as the TLX inverters come in different power sizes the PV to AC ratio can be optimised ensuring that you always get the most efficient system for the area available.

Having ensured the optimum configuration for PV input, it is important to likewise consider the conditions for output.

Grid and AC configuration

Despite ongoing harmonisation, delivery of the produced energy to the grid is no simple task. It is linked to both the size of your installation and to the type of grid. Different countries do not just have different requirements but within the country grid requirements may also depend on the amount of power supplied.
The characteristics of the TLX inverters regarding the AC side are:

- Three phased output 3x400 $V_{AC\ L\text{-}L}$
- Grid settings for 17 countries including ancillary service functionalities

In larger systems with several inverters considerations into inverter location also becomes relevant, taking AC cabling versus DC cabling into account.

3.1 Point of connection (PC)

The point of connection (PC) is where the PV system is connected to the public electricity grid.
The PC is evaluated and selected by the DNO under consideration that the selected point should not affect the performance, and the generated power should not interfere with the grid, power supply or the connected power consumption device.
This is to electrically isolate the PV power generation system and the power consumption circuit. More PV systems can be connected to the common point, though the total power generation capacity should be taken into consideration.

3.2 AC configuration

TLX inverters are designed to receive a high DC voltage level. It is thus possible to span long distances with standard PV cables, increasing the flexibility in terms of finding the optimum position for mounting the inverters. Generally, the lowest costs for DC and AC cabling can be obtained by concentrating larger numbers of inverters in one place, ideally near the MV transformer or the low voltage feed-in point.

When installing a PV system on several buildings, the installer can choose to install the inverters in groups per building or utilise the high DC voltage of TLX inverters to unite all inverters in one place. This flexibility minimises cable losses, cable installation costs and AC sub-distributions.

Beyond the standard AC cable for connecting the inverters to the AC sub-distribution, no (or only one) additional AC cable type is need to connect the transformer. The reduced number of AC sub-distributions also contributes to the cost-saving potential of string inverters.

3.3 Low voltage grid

For system output power levels of between 400 kVA and 600 kVA AC, it is often possible to connect the inverters directly to the low voltage grid. The low voltage (LV) distribution system carries fewer requirements compared to the medium voltage (MV) grid. However, there is a clear tendency that regulations for the MV grid become increasingly adapted in the LV grid, thus grid support functions are now also required in the LV grid to some extent.

3.3.1 Ancillary services for low voltage grid system

An example of required grid support (ancillary services) is found in Germany, where as of July 2011, requirements will take effect concerning active power reduction and the control of reactive power.
Power reduction must be carried out at excess frequencies for all installations. Reduction based on input from the DNO is only relevant for systems over 100 kVA. The remote control device for power management provided by the DNO can be connected to the Danfoss Grid Management Box. This box controls the output power reduction of the TLX Pro inverter PV system The power can be reduced by 0%, 30% or 60%, or it can be restored to 100% according to the needs of the utility company to keep the grid stable.

Additionally TLX Inverters will able to control reactive power, either as a fixed value of Cos(φ), or as a function of the generated power when selecting the country setting Germany LV by 1-7- 2011.

3.4 Medium voltage grid

PV systems with more than 400 kVA AC output power typically have to be connected to MV grid. Therefore you need a MV transformer as interface to the grid. The German BDEW has compiled a technical guideline for energy generating systems connected to the MV grid. Other countries have (or will have) similar directives. In this directive it is stated how PV systems have to contribute to the grid management.

3.4.1 Ancillary services in medium voltage grid system

The requirements from grid suppliers have recently been expanded in several countries. For all PV power plants connected directly to the MV grid, it is now commonly seen that there is a requirement to support the grid stability. Thus for counties with such requirements it is possible to select a country setting, (indicated by "MV") during inverter setup. Once selected the relevant ancillary services will be activated. Depending on the type of ancillary service required you may need external input to control them. For this purpose the Grid Management Box must be connected. The Grid Management Box is an interface between the DNO's equipment and the inverter network communication system, through which the parameters and settings are controlled. To date, Germany is the country having implemented the largest number of support requirements, including active power reduction, control of reactive power and support during grid faults.

Power reduction must be carried out both at excess frequencies and based on input from the DNO. Input from the DNO to control the amount of power reduction is transmitted via a remote control signal, which ends in four relay outputs determining whether 0%, 30%, 60% or 100 % of the nominal power will be allowed to be delivered.

Support of reactive power may be based on different schemes, which range from the most basic, with a fixed value of power factor [fixed PF] or reactive power [fixed Q] to the power factor being automatically controlled as function of the power [PF(P)] or as a function of the grid voltage [Q(U)].

To help the gird during error situations, the inverter must be capable of remaining on grid for a defined period, despite the absence of grid voltage. During this period the inverter will continue to deliver reactive current, which will help to re-establish the grid voltage once the grid error begins to clear. The TLX Pro + inverters are able to support all the different requirements when connected to the Grid Management Box.

3.5 Transformer station

When connecting to the MV grid a transformer station is needed. If there is adequate room available a stand-alone transformer station can be placed centrally within the installation area. It can also be required or recommended to use a compact transformer station outside the building carrying the PV system. For ground mounted plants this will be the preferred solution. The transformers or compact stations are available in various standard sizes and are among the most commonly used. They usually have short lead times. The stations can be ordered prefabricated, which will also reduce installation effort and cost.
The use of a low-loss transformer reduces the nightly power consumption of the transformer to below 0.4% of yearly production. Consequently, short circuit losses in the transformer have little effect on overall yield. In the medium voltage area of transformers of up to 1000 kVA, outgoing feeder panels with HH-fuses can be inserted instead of the more expensive power switches.

3.6 System approval for connection to MV grid

Generally you need approval to connect to the MV grid. You therefore need to contact your DNO for the procedure.
As an example, the procedure for connecting to the MV grid in Germany is explained.
In order for a PV plant to be connected to the MV grid in Germany a four-step procedure must be followed. The procedure is outlined in the technical guideline from BDEW. First, the Plant Owner must apply to the DNO. The application must include a data sheet and unit certificate for the inverter. Based on the application, the DNO will then inform the plant owner about the amount of power that may be connected [SKV, ΨK]. Based on this information the owner can then erect the plant, and a plant certificate can be prepared by a plant certification office. The plant certificate will include a grid simulation of the plant. For this purpose the plant certifier will require a simulation model of the inverter, which can be obtained directly from Danfoss, should the certifier not have one already.

3.7 Conclusion

The TLX inverters will ensure that the energy produced is supplied to the grid in accordance with all standards and legislation without causing trouble in installation.

The inverter will always deliver a symmetrical output, and includes setting functionalities for compliance with all grid regulations in the range of 17 countries.

Having designed the best solution for the application it is of interest to include monitoring of overall system performance and status in order to verify that the investment performs as expected and to enable you to act before potential problems escalate.

Communication and monitoring

Having spent time on optimising your PV system, refining it to harvest as much as possible of the energy from the PV modules and feeding it into the grid you will also want to ensure the system continues to do so. Thanks to modern hardware and sophisticated software, the TLX inverter range includes detailed data logging functionalities supporting the desired monitoring. Whether you want to use a built-in or external solution TLX inverters provide multiple ways of interaction:

- Integrated Web server
- External products

Depending on your preferred type of interaction different ways of communication may be relevant:

- Ethernet communication
- RS-485 communication
- GSM communication

To aid both the interaction and communication processes in systems having multiple inverters various supporting functionalities have been collected in what is know as Master Functionality.

Ancillary services requiring central control and input also use the communication system for distribution of the required control signals.

In the following we will initially describe the communication possibilities that form the foundation for the different interaction possibilities. These are subsequently described. Additionally the web server and master functions are covered before accessory products are mentioned.

4.1 Monitoring options

For a power plant with an output level of several hundred Kilowatts, it is common practice to connect to the medium voltage grid. Therefore a power plant system of this size must enable all grid support functionalities for medium voltage grids. If the power plant is to be connect to the low voltage grid, only some grid supportive functions for low voltage are required, i.e. power level adjustment (PLA).

The TLX Pro includes a cost-efficient solution to get logging and monitoring functionalities as it includes an extensive web interface accessible via Ethernet. All individual and accumulated system parameters are accessible through the master inverter, providing a single point of access to the entire inverter communication network where control and grid management parameters can be set-up.

4.1.1 Integrated Monitoring, Ethernet communication

The TLX Pro is equipped with high logging capacity (Storage capacity is 34 days at 10-minute intervals). Logging intervals may be changed (Every minute, 10 min or every hour).
The data logged in the inverter is accessed via a LAN connection to the inverter. The LAN network can be configured in two ways:

a) Direct access

Connect you computer directly to the TLX Pro master inverter via LAN:

- Automatic Addressing (APIPA), no router, no DHCP
- Local access from computer through Explorer or Firefox,

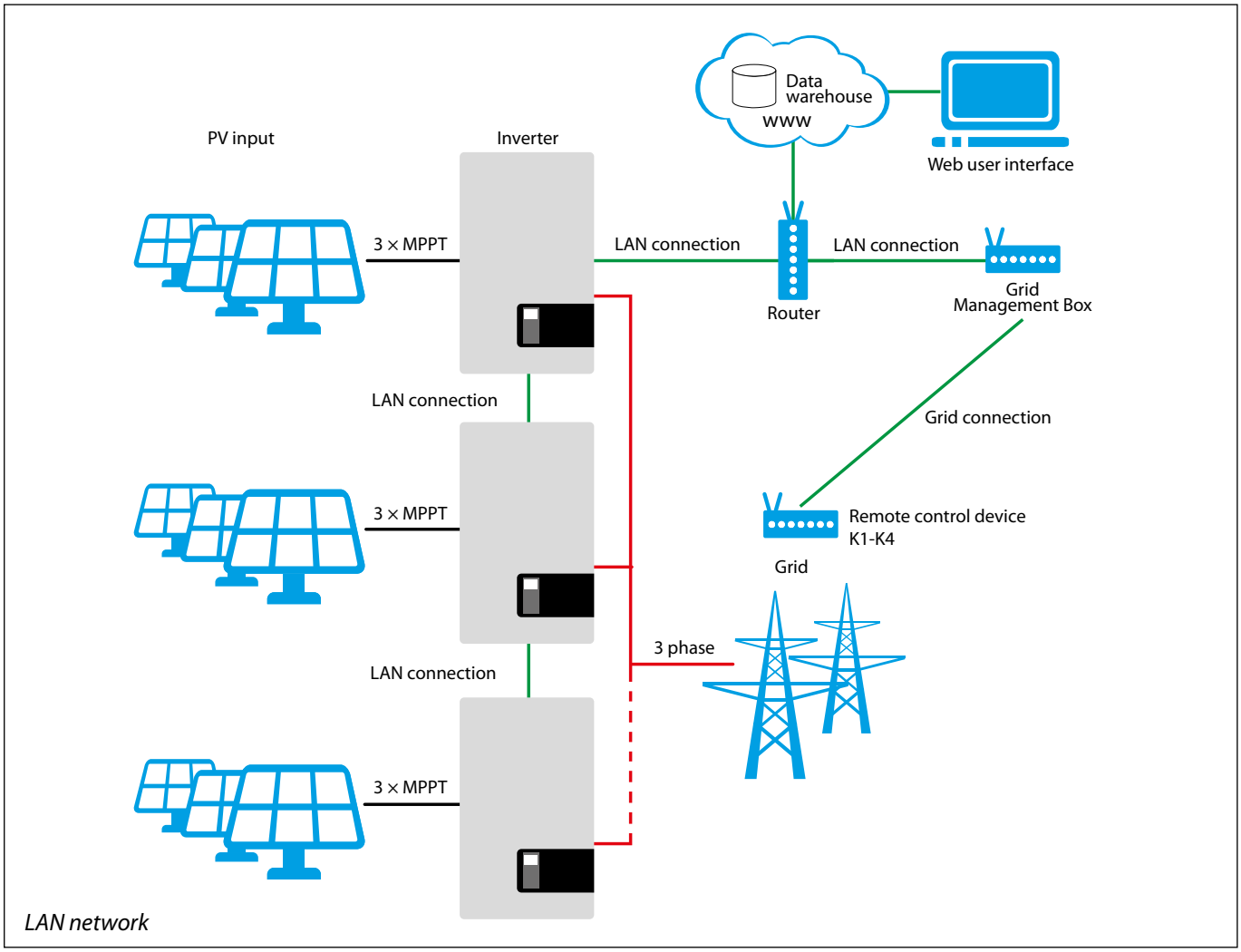
Providing you with an extensive administration and monitoring interface through the integrated Web server

b) Internet access

Connect a TLX Pro master inverter via LAN to a router, then to Internet; see figure.

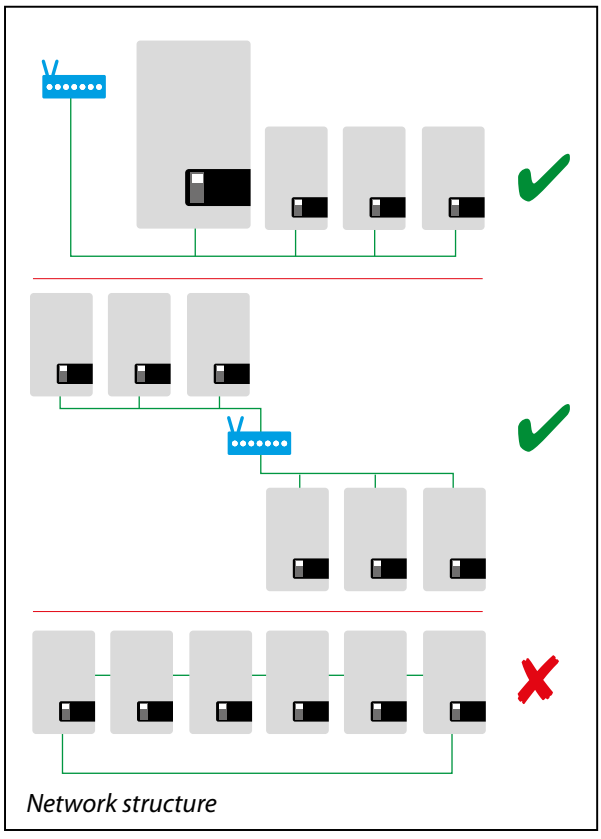
- Router with DHCP assigning IP addresses to hosts (inverters and computers)
- Local access to inverters from local computer through Explorer or Firefox
- Access to inverters from the Internet through Explorer or Firefox
- Requires configuration of router NAT tables

Providing you with an extensive administration and monitoring interface through the integrated Web server, and allows for data to be sent via FTP to a data warehouse service, or as e-mail to specified recipients



LAN network

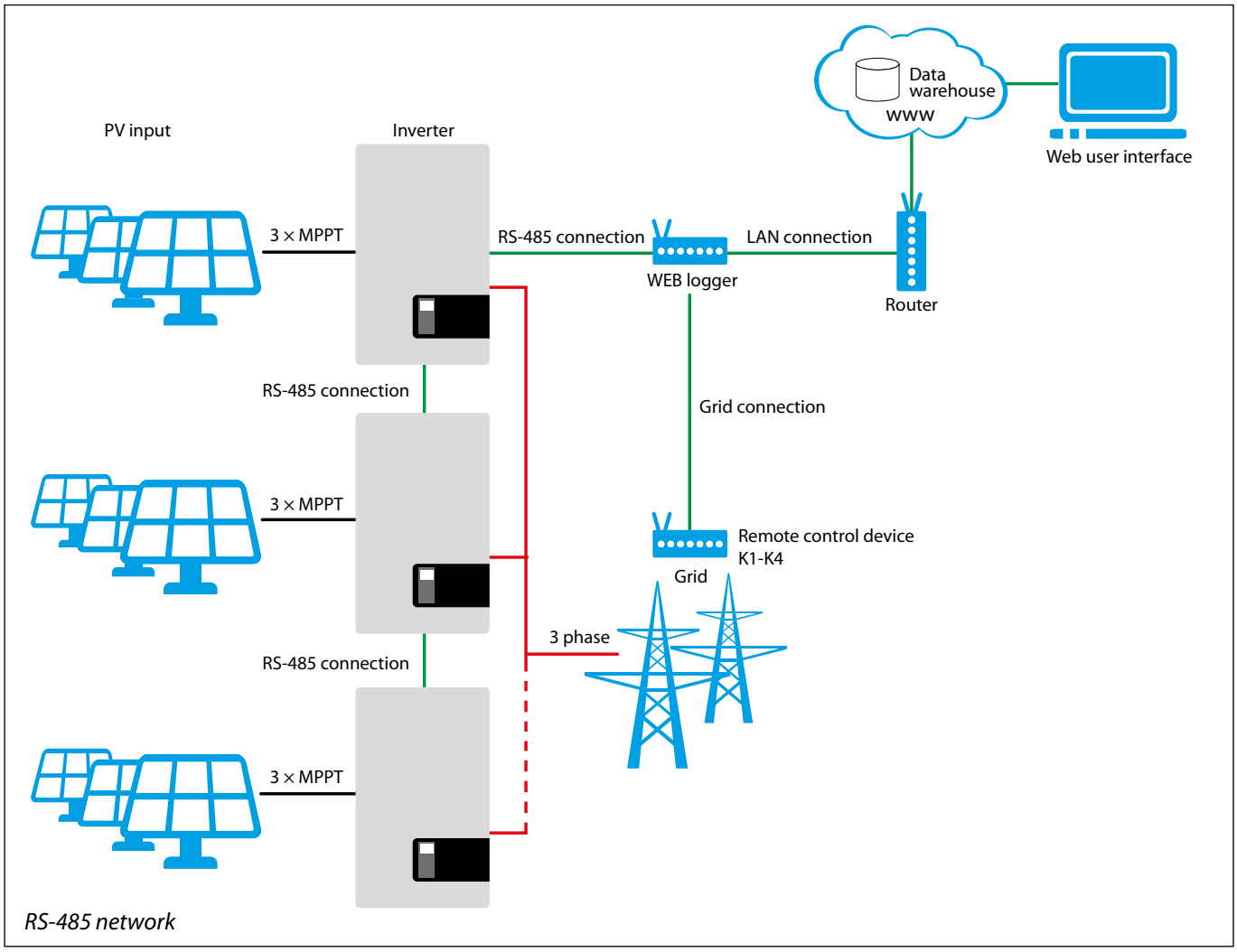
Network Structure



Network structure

4.1.2 RS-485 communication

As alternative to the integrated monitoring a data logger or web logger (Comlynx range or a third-party unit) can be connected to the inverter through RS-485 communication. These units are then accessible through a computer, for monitoring. The RS-485 ComLynx protocol is open and free for download if you want to write your own communication solution.



RS-485 network

4.1.3 GSM communication

A TLX inverter may be upgraded with a GSM modem. This allows data to be transmitted through GSM to external data warehouses or as SMS.

Note: In inverter networks with TLX Pro inverters only the defined master inverter need upgrading with the GSM Modem

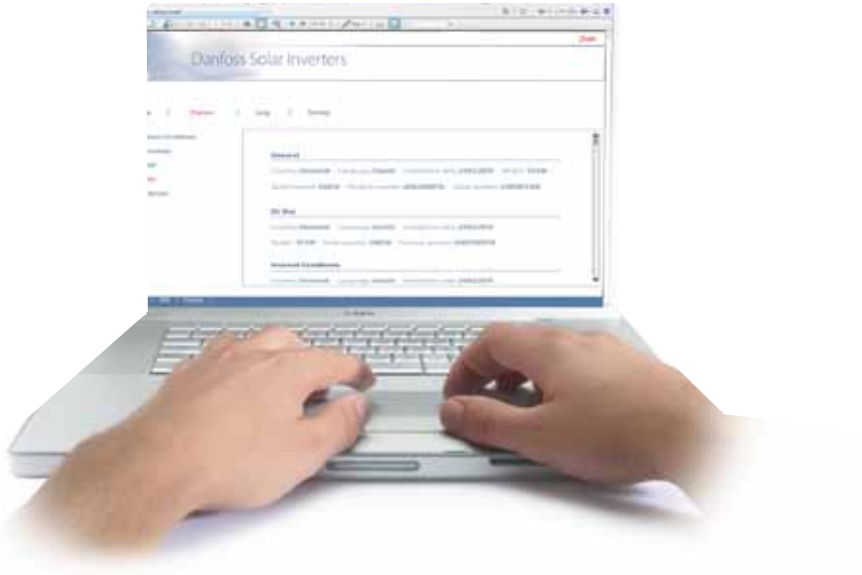
4.2 Web server

Through the Ethernet network the logged data can be accessed by using the Web server, which is included in all TLX Pro inverters. Once the network has been established, all you need it to do is to open a browser (Explorer or Firefox) and type in the inverter name in the address field. Via the Web server, you can access all relevant parameters, however, faster, easier and more illustrative than through the display.

The Web server allows you to monitor or change:

- Inverter/plant setup
- Power plant status
- Show graphics and curves (yield, or reduced CO2 emission, etc.)
- Set up communication (e-mail or SMS to recipients)
- Dynamic language selection between eight languages

In addition, the data can be exported in different forms, and data analyses and comparisons can be performed.



4.3 Master functionality

TLX Pro inverters feature a Master/Follower function. Every TLX Pro inverter can be defined as a master inverter with unidirectional control over one or more inverters.
With master functionality, setup, commissioning, monitoring will be significantly simplified, as it allows you to:

- Collect and summarize data from entire inverter communication network
- Upload data to data warehouse service
- Distribute emails or SMS
- Replicate data from Master inverter to followers (inverter/plant set-up)

4.4 Comlynx Datalogger

For extra storage capacity the PV installation may be equipped with external logging units, using the RS-485 communication network.
You thereby obtain between 1.5 – 4 years of storage capacity and communication based on the RS-485 protocol.

Danfoss offers a range of data and web loggers in the ComLynx range.

- ComLynx Datalogger and ComLynx Datalogger +, which is equipped with a sensor interface
- ComLynx Weblogger with a matching sensor interface

The Comlynx range translates and transmits all important parameters (yield, inverter events, etc) from the inverter to a computer or a modem for remote access.
In addition to Danfoss Comlynx range, several other monitoring solutions are compatible with Danfoss solar inverters. Consult your supplier for the proper application.

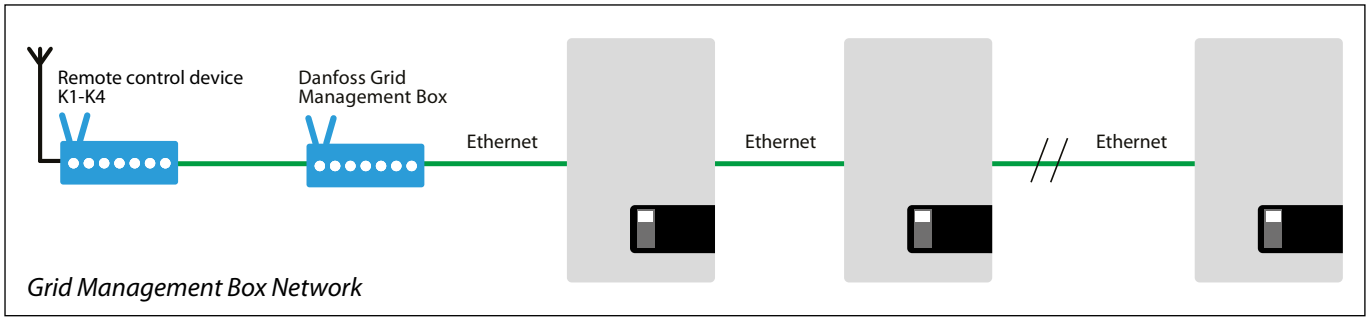
4.5 System accessories

4.5.1 Grid Management Box

The Danfoss Grid Management Box is designed to support the master functionality of the TLX Pro and TLX Pro+ inverter to meet today's dynamic grid requirements. After receiving the control signal from grid (DNO), the Grid Management Box translates the commands to the master inverter, which then perform the following as needed:

- Reactive power exchange
- Power level adjustment

Note: The Danfoss Grid Management Box is only applicable with TLX Pro and TLX Pro+, and the grid management function of TLX Pro and TLX Pro+ can only be used through the Danfoss Grid Management Box.
The following schema shows the position of the grid management box:



Grid Management Box Network

4.5.1 Router

In order to enable communication between the internet and inverters, a router should be used for "traffic directing" functions, i.e. a router with DHCP assigning IP addresses to hosts (inverters and computers). A configuration of the router NAT tables should be performed.

Home or small office routers are insufficient for medium and large scale commercial installations due to the amount of data traffic. A professional router must be employed, which is capable of handling the data amount. In order to properly match the application and ensure correct set-up you need to involve a network or IT specialist.

4.5.2 Sensor kit

Sensors can be connected directly to the sensor interface integrated in the TLX Pro master inverter. External sensors are used to provide sophisticated monitoring of ambient conditions for accurate calculation of performance.

Danfoss offers a sensor kit including:

- Irradiation sensor
- Module temperature sensor
- Ambient temperature sensor

4.5.3 Energy Meter Sensor (S0)

Input from an energy meter is supported according to EN62053-31, Annex D. S0 is a logical count input.
The energy meter input is presented via the display, Web server or external monitoring solution.

4.6 Conclusion

The monitoring options allow you to actively follow the PV installation, whereby potential problems can be identified quickly. If service is required, troubleshooting is easy to perform as the detailed system overview allows you to narrow down the potential causes. With integrated monitoring solutions you get the advantages of a full monitoring system, without the hassle of having to connect more units.
All grid management tasks are also handled through an integrated solution from a single supplier.

Easy installation and as simple cabling and handling as possible, is something, which is always top of mind

5.

Installation

The low weight and small dimensions of string inverters allow for easy positioning of the unit within the space already available in/on the building or ground mounting structure.

- 35 kg
- 700×525×250 mm

TLX inverters with IP54 enclosures are suitable for outdoor installations and need no extra shelter when mounted in the shade. However, an inverter can also be mounted inside a building provided that it is in a well-ventilated room. If the plant is located at an elevation above 1000 m, additional considerations must be taken into account regarding the layout factor in order to compensate for the lower cooling effect, resulting from the thin air.

5.1 Inverters locations

For roof top systems an installation location inside the building that carries the PV system is often preferred. Using TLX inverters you only have two or three pairs of DC cables throughout the building per inverter. However some types of solar modules demand a higher number of strings. In such cases it is possible to connect pairs of strings in parallel by using Y-connectors at the PV array. For ground mounted installations mounting the inverter under the modules is advisable, as the modules can provide shelter from direct sun and rain.

5.2 Cabling

5.2.1 AC

Standard AC cables with cross-sections of up to 10 mm^2 can be connected directly to the inverter. This enables 15 kVA inverters to span distances to the feed-in point of up to 60 m without increased cable losses. Smaller cables with cross-sections of 6 mm^2 or 4 mm^2 can also be used. The cables must be 5-wire cables.

5.2.2 DC

In most cases, standard PV cable with a 4-mm^2 or 6-mm^2 cross-section is the best choice to connect the module strings to the inverter. Reasonable cable losses are kept if you use 4 mm^2 or 6 mm^2 cables over total distances of up to 100 m or 300m respectively. Another cost-saving opportunity lies in the option of connecting all strings of one inverter in parallel. After the parallel connection of the strings at the PV array, you can span distances of several hundred metres using a pair of standard DC copper cables with cross-sections of 25 mm^2 or 35 mm^2. The inverter will subsequently operate in parallel mode, once you divide the power between all DC inputs of the inverter

5.2.3 Communication cables

Ethernet connection requires:

- Cat 5 cable
- Between a TLX Pro inverter and a computer /internet
- Between TLX Pro inverters

RS-485 connection requires:

- Cat 5 cable
- Between a web-logger and an inverter
- Between inverters (note: no Pro functionalities)

5.3 Conclusion

The easy handling of the TLX inverters means full flexibility in installation location.
The complete system; perfectly designed, installed and monitored will be encompassed by the security of the Danfoss service system.

Service/reliability

String inverters have the benefit of being commercially available standard component. Unlike central inverters, special training is not required to be able to install, maintain or exchange string inverters. The local electrician can maintain the string inverter installation, meaning that service contracts requiring specialists from the inverter manufacturer are not required. For service purposes, backup of settings and data is available in the inverter display enabling a quick exchange. Furthermore, by omitting junction boxes, no service on the DC side is required.
The availability of the installation is very high as only a smaller part of the system will be affected if modules or inverters should fail.

However, if any problems or issues arise Danfoss' extensive service network ensures the installation is taken care of.
The service hotline is available during normal business hours. Service is offered in five languages – English, German, French, Spanish and Italian – and the service personnel know exactly how to provide the technical support you need.
If an exchange inverter is required, we guarantee that it is shipped as soon as possible and within no more than 24 hours.
If the service issue cannot be solved by our Hotline guidance or by an exchange of inverter, On-Site service teams are prepared for the task, which is initiated within 24 hours. The service teams consist of experienced technicians with special training in solar inverters and PV systems.

The standard warranty is five-years extendable to ten years.

Functionalities		Relevant grid type	TLX	TLX+	TLX Pro	TLX Pro+
Master functionality	Ethernet communication				x	x
	Distribution of settings					
	Software update from master inverter					
	Data upload					
Integrated logger	Inverter setings backup				x	x
	Storage capacity		3 days	3 days	34 days	34 days
	Interface for sensors		x	x	x	x
Included monitoring	Ethernet communication				x	x
	Web server					
	Alarms					
Comlynx monitoring	RS-485 communication		x	x	x	x
	Data upload					
	Alarms					
3rd party monitoring	RS-485 communication		x	x	x	x
	Data upload					
	Alarms					
GSM modem	Data upload to FTP servier		x	x	x	x
	Data upload through master inverter				x	x
Ancillary services using master functionality and grid management box	PLA	LV/MV			x	x
	P(F)	LV/MV				x
	PF	MV				x
	Q	MV				x
	PF(P)	MV				x
	Q(U)	MV				x
	Fault Ride Through	MV				x
Ancillary services using none or 3rd party product	PLA	LV/MV	x	x	x	x
	P(F)	LV/MV		x		x
	PF	MV		x		x
	Q	MV		x		x
	PF(P)	MV				x
	Q(U)	MV				
	Fault Ride Through	MV		x		x

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