MAKING MODERN LIVING POSSIBLE

Small commercial inverter solutions **based on TLX Pro**

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Preface

With systems of between 15 kVA and 100 kVA predominating in many markets, it makes competitive sense to choose a solution developed to maximise yields.
To be successful in this increasingly competitive market environment you have to pay attention to details in the design and hardware of the PV system.
Using just a few TLX inverters you can optimise PV systems by taking advantage of the numerous MPP trackers. This simplifies the system design and installation. Furthermore, TLX Pro inverters include features that give a high degree of competitiveness; such as the high inverter efficiency and integrated monitoring functionality.

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.

The present paper targets small commercial applications, which for the purpose of this paper are defined as installations with multiple TLX inverters with a total grid connection of less than 100 kVA.

Ideally, a 100 kVA PV system can be built up using only six inverters with a weight of only 35 kg per device. All types of TLX inverters can be combined in any order to meet the ideal ratio between power of the PV strings and the AC power of the inverters. Hence you are able to obtain the best price performance ratio. Due to the inverter's three-phase output, it is not necessary to adopt measures to ensure AC phase synchronicity. The average PV power of 5.5 kWp or 4.5 kWp per MPPT provides a very accurate tracking of PV module strings, even if there are, for example, high temperature differences in the module array.
For every MPPT the DC current and voltage are monitored. This ensures a high level of control of operations and maximal system reliability without additional string monitoring hardware. The multiple MPPTs also allows a high level of flexibility in DC design of the PV system. It is therefore possible to obtain a string voltage near the nominal DC voltage of the inverter. This ensures inverter operation with highest possible efficiency and best possible yield.

The TLX Pro inverter has a built-in monitoring system. This means there is no need for connecting a separate unit. All Pro inverters are able to function as the system master, providing the monitoring interface for the complete plant. Connecting the other inverters in the system to the master via Ethernet LAN can be in star or daisy chain configuration, depending on the installer's preference. Once connected, an IP address will be set up automatically. Installers can also use the inverter's built-in web interface to simplify installation. Via the master inverter it is possible to replicate the setup parameters to other inverters in the plant. Communication cabling and system setup are thereby simplified, reducing installation time and the number of installation errors.

Using the built-in monitoring system more end users will benefit from keeping track of system status. Hereby faults in the plants can be early detected and immediately corrected, resulting in less system downtime. Easily understandable information will be available from the users' own PC using a standard browser. An overview of the complete plant or details from an individual inverter can be obtained by the user via the simple web interface of the master inverter. More experienced users may set up e-mail or SMS notification regarding plant status.

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 characteristics:

- 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 deeper 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)

The TLX inverters have a maximum PV power per MPPT of 4.5 kWp or 5.5 kWp enabling output to be optimised without accepting higher costs. With the multiple MPPT and the four power sizes of TLX inverters you can find a solution for every number of modules, which will maximize yield and minimize cost. Partial shadings and different roof area orientations can be handled without excess effort in system design. By minimisation of the number of strings, it is possible to; get an individually regulated MPP tracker per string; the string operates with voltage values near the nominal DC voltage of the inverter, and the higher DC voltage reduces cable losses.

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 6mm^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 allow a high DC voltage level. It is thereby possible to span long distances with standard PV cable, which increases the flexibility of finding the ideal position for mounting the inverters. The lowest costs for DC and AC cabling can generally be obtained by concentrating all inverters in one place, ideally near 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.

3.2.1 Low voltage grid

Small commercial installations up to 100 kVA are usually connected to the low voltage (LV) distribution system which 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.

3.2.2 Ancillary services in 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.
TLX+ and TLX Pro+ inverters are therefore 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

3.3 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.

4.

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
- Integrated Display

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

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.

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,

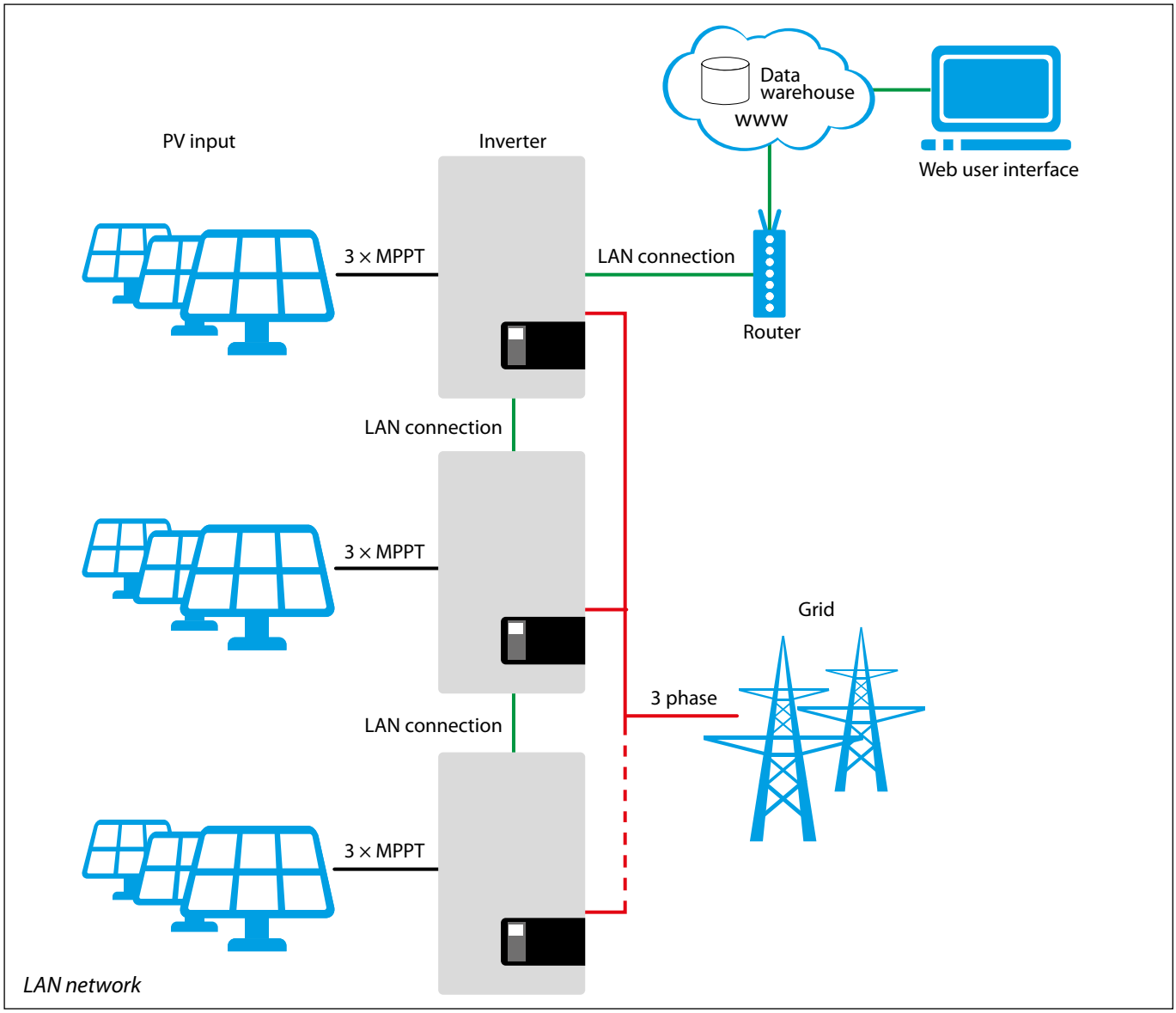
Providing you with an extensive administration and monitoring interface through the integrated Web server

b) Internet access

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

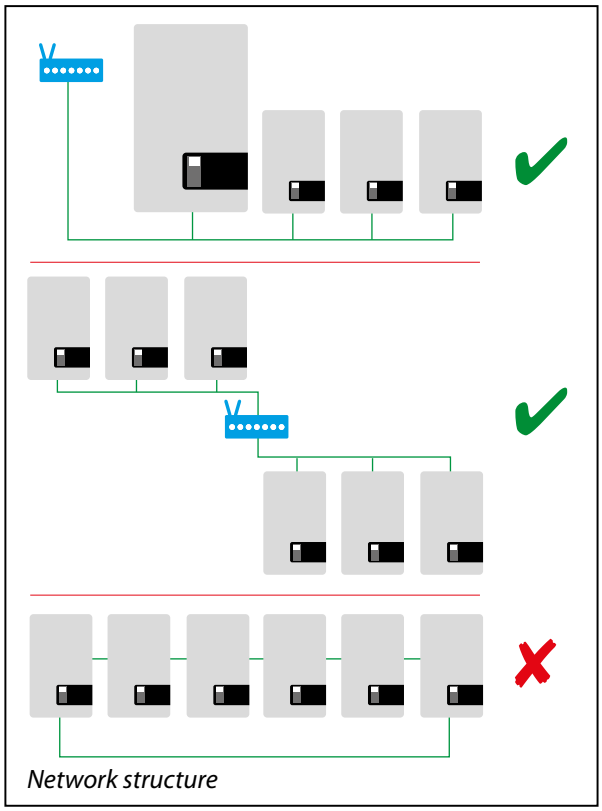
- Router with DHCP assigning IP addresses to hosts (inverters and computers)
- Local access to inverters from local computer through Explorer or Firefox
- Access to inverters from the Internet through Explorer or Firefox
- Requires configuration of router NAT tables

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

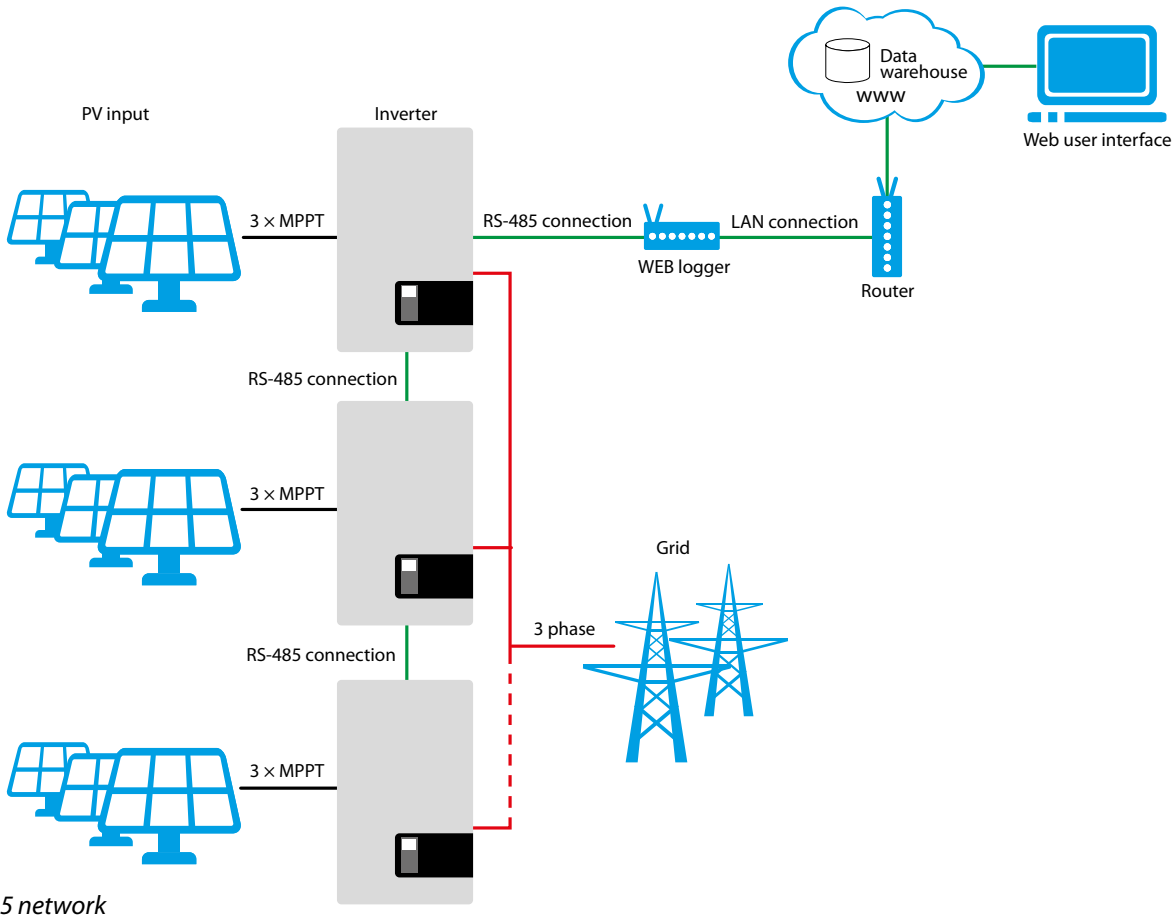
Network Structure



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 purposes. The RS-485 ComLynx protocol is open and free for download if you want to write your own communication solution.



RS-485 network

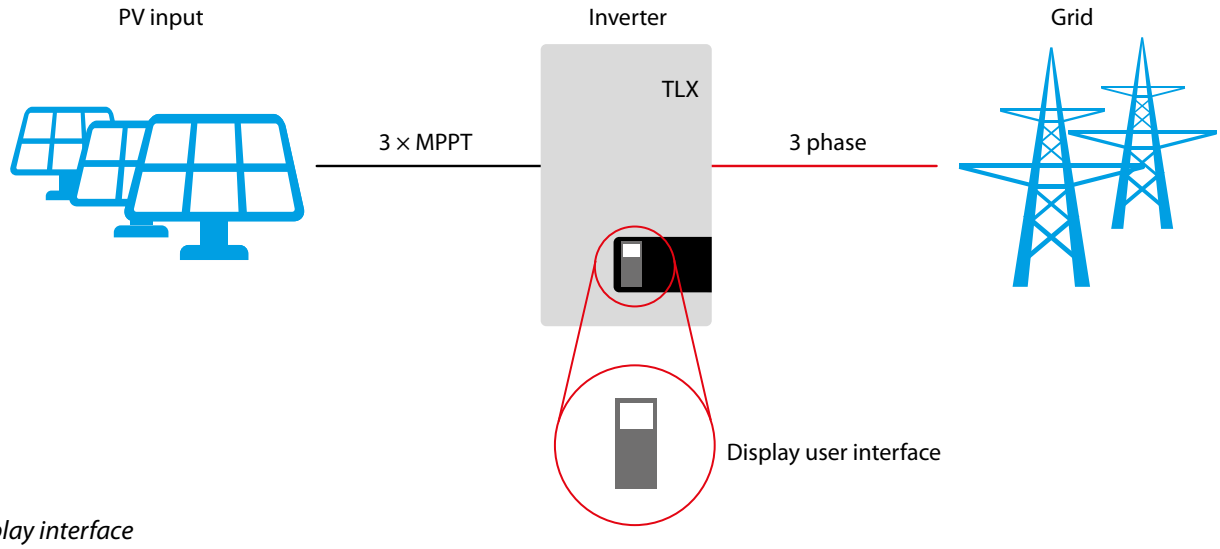
4.1.3 GSM Communication

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 ungrading with the GSM Modem.

4.1.4 Display

It is always possible to monitor the inverter via the display. It also provides an extensive user interface.



Display interface

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 CO_2 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 services
- 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 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 sufficient for small commercial installations.

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.

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

Installation

The low weight and small dimensions of string inverters allow for the easy positioning of the unit within the space already available in/on the building.
Inverter characteristics:

- 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, the unit can also be mounted inside the 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 Inverter locations

In most cases an installation location inside the building that carries the PV system is preferred. Using TLX inverters you only have to install two or three of DC cables throughout the house 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.

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 is to be used
- Between a TLX Pro inverter and a computer /internet
- Between TLX Pro inverters

RS-485 connection requires

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

RS232 connection requires:

- Modem cable
- Between data-logger/web-logger and modem (modem cable)
- Null modem cable
- Between data-logger and PC

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.

6.

Service/reliability

String inverters have the benefit of being commercially available as a standard component. This means that it is possible to let a local installer or plant supervisor with no special training carry out exchange of the inverter if necessary. Therefore, service contracts directly with the inverter manufacture are not necessary for string inverters. Furthermore, in case of failure only a smaller part of the system will be affected.
The 5-year warranty remains unchanged for inverters used in large plant applications, and warranty extensions of up to 10 years are possible.
To aid the installer or plant supervisor during fault finding, each inverter comes with a display.

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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