Aspects of a generic photovoltaic model examined under the German Grid Code for Medium Voltage

Ioannis-Thomas Theologitis[1], Eckehard Troester[2], Thomas Ackermann[3]

Abstract--The increasing penetration of photovoltaic power systems into the power grid has attached attention to the issue of ensuring the smooth absorbance of the solar energy, while securing the normal and steady operation of the grid as well. Nowadays, the PV systems must meet a number of technical requirements to address this issue.

This paper investigates a generic grid-connected photovoltaic model that was developed by DIgSILENT and is part of the library in the new version of PowerFactory v.14.1 software that is used in this study. The model has a nominal rated peak power of 0.5 MVA and a designed power factor cosφ=0.95. The study focuses on the description of the model, its control system and its ability to reflect important requirements that a grid-connected PV system should have by January 2011 according to the German grid code for medium voltage. The model undergoes various simulations. Static voltage support, active power control and dynamic voltage support – Fault Ride Through (FRT) is examined.

The results show that the generic model is capable for active power reduction under over-frequency occasions and FRT behavior in cases of voltage dips. The reactive power control that is added in the model improves the control system and makes the model capable for static voltage support in sudden active power injection changes at the point of common coupling.

Beside the simplifications and shortcomings of this generic model, basic requirements of the modern PV systems can be addressed. Further improvements could make it more complete and applicable for more detailed studies.

Index Terms--**Grid-connected Photovoltaic, PV inverter, German Grid Code for MV, PV model, PowerFactory of DIgSILENT, Reactive power control**

I. NOMENCLATURE

AC – Alternative Current
DC – Direct Current
DIgSILENT – Digital SImuLator for Electrical NeTwork
FRT – Fault Ride Through (Low Voltage Ride Through)
LV – Low Voltage
MPP – Maximum Power Point
MV – Medium Voltage
PCC – Point of Common Coupling
PF – Power Factor
PLL – Phase Locked Loop
PV – Photovoltaic
PVPS – Photovoltaic Power Systems
Q – Reactive power
RET – Renewable Energy Technology
STC – Standard Test Condition

II. INTRODUCTION

The great potential in Renewable Energy Technologies (RET) has been seen since a long time ago. However, mostly technical and economical restrictions combined with the lack of a defined policy context around these technologies, has prevented the large scale deployment. Nevertheless, the increasing demand of energy due to population growth, the target of energy-independence from fossil fuels (mostly coal) set by many countries, the general need for more carbon-free energy sources due to environmental reasons and the legislation scheme that has been started to take form, have brought RET to the fore, especially the last decade.

Germany is a strong example of a country that has invested time and money towards renewable energy evolvement. Its leading position in the field among the EU countries and its key role worldwide, especially in wind and solar power, are reflected by facts. As far as the PV technology is concerned, by September 2010 the total number of installed capacity was 15 GWp, which was almost 30% of the total RET installed and 37.5% of the minimum electricity load of 2009 [1].

Germany has set a goal of 38.6% renewable electricity share [2] and in order to achieve that, PV technology should contribute significantly. Fig.1 presents a future scenario showing the increment of the installed PV capacity and the relevant PV price share of the total additional cost per kWh.

However, this PV penetration must not jeopardize the normal operation of the power grid. Thus, technical specifications should ensure and facilitate the proper interconnection and reinforcement of the grid. According to the German grid code any distributed generation plants should support the steady state operation (e.g. provide reactive power) and contribute to the stability of the power grid in cases of fault (e.g. voltage dips) at the connection point.

---

[1] Intern at Energynautics GmbH, Mühlstrasse 51, 63225 Langen, Germany (e-mail: i.t.theologitis@energynautics.com)

[2] Senior engineer at Energynautics GmbH, Mühlstrasse 51, 63225 Langen, Germany (e-mail: e.troester@energynautics.com)

[3] CEO at Energynautics GmbH, Mühlstrasse 51, 63225 Langen, Germany (e-mail: t.ackermann@energynautics.com)

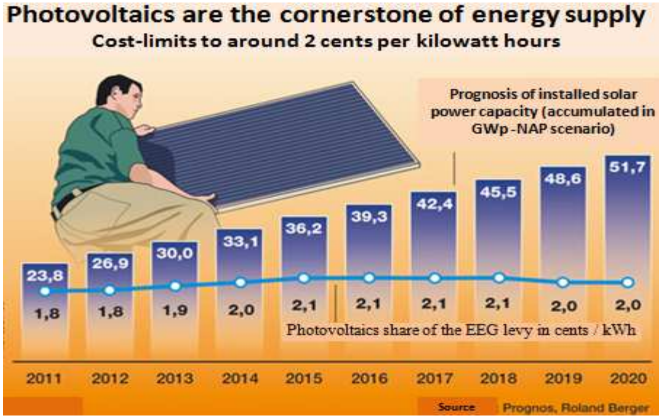


Fig. 1. Future scenario of PV installed capacity and renewable electricity levy for the next decade in Germany [3]

Photovoltaic Power Systems (PVPS) are connected mostly to the low and medium-voltage network and only approximately 1% of the total PV installations is connected to the high voltage network [1], meaning that the demand for grid stability refers to the low and medium voltage networks. Table 1 aggregates the basic requirements that grid-tied generators should meet in order to be integrated to the network. In this study the focus is:

- Active power control
- Dynamic voltage support – FRT
- Static voltage support

Certainly there are other requirements and issues to be considered when designing a grid-connected inverter that include power quality problems (e.g. harmonics), safety issues (e.g. anti-islanding protection, under /over voltage protection, under/over frequency protection), electromagnetic interference etc. Those issues usually follow local rules that have been adopted by general European or International standards. Some examples can be found in [5].

III. MODEL

The PV model that is analyzed in this paper is developed using a static generator and can be seen in Fig.2.

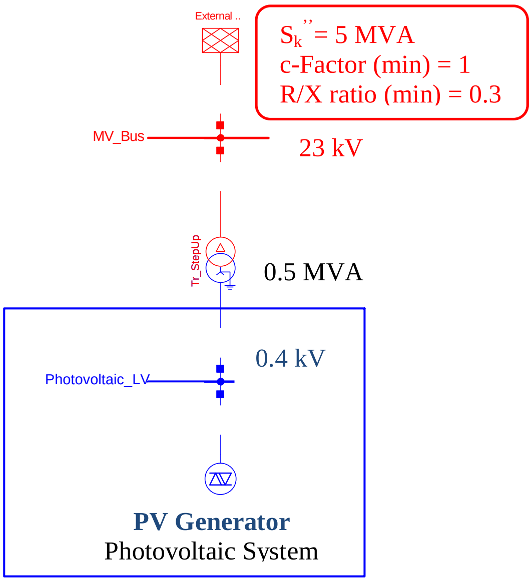


Fig. 2. The PV system model

TABLE 1. NEW REQUIREMENTS FOR GRID TIED GENERATORS [4] [7]

Grid Codes	Voltage Band	Fault Ride Through	Reactive Power Supply			Frequency Band	Active Power Derating
	range	capability	capability	range	function	range	capability
High Voltage (>110 kV)	0,8 U_N ↔ 1,16 U_N	√	√	Based on 3 different possible variants*: $0{,}228_{leading} < Q/P_n < 0{,}48_{lagging}$ $0{,}33_{leading} < Q/P_n < 0{,}41_{lagging}$ $0{,}41_{leading} < Q/P_n < 0{,}33_{lagging}$	Q(U) $\cos\varphi_{fix}$ Q_{fix}	47,5 Hz ↔ 51,5 Hz	√ function $\Delta(\frac{P}{P_M}) = 40\frac{\%}{Hz}(50,2Hz - f)$ $50,2Hz < f < 51,5Hz$
Medium Voltage (<110 kV & >10 kV)	0,9 U_N ↔ 1,15 U_N	√	√	$0{,}95_{lagging}$ to $0{,}95_{leading}$	$\cos\varphi(P)$ Q(U) $\cos\varphi_{fix}$ Q_{fix}	47,5 Hz ↔ 51,5 Hz	capability √ function $\Delta(\frac{P}{P_M}) = 40\frac{\%}{Hz}(50,2Hz - f)$ $50,2Hz < f < 51,5Hz$
Low Voltage (<10 KV)	0,9 U_N ↔ 1,15 U_N	√**	√	$0{,}90_{lagging}$ to $0{,}90_{leading}$***	$\cos\varphi(P)$ $\cos\varphi_{fix}$	47,5 Hz ↔ 50,2 Hz	capability √ function $\Delta(\frac{P}{P_M}) = 40\frac{\%}{Hz}(50,2Hz - f)$ $50,2Hz < f < 51,5Hz$

* Also dependent on the voltage level at the PCC [6]. Below $P/P_n = 0{,}2$ reduced reactive power can be provided.

** However, no reactive current injection is defined [7]

*** Depending on the total apparent power of the plant [7]

It is a generic model that was built by DIgSILENT as part of a past study and is available in the newest version of the PowerFactory tool. The template consists of the PV generator with a number of control systems and design features, which are integrated in it and also a Low Voltage (LV) terminal of nominal voltage 0.4 kV that the generator is connected with. The capacity of the system is 0.5 MVA. The rest of the configuration, which includes an external grid component, a MV bus bar of 23 kV nominal voltage and a step up transformer of 0.5 MVA rated power, were used in order to serve the needs of the examination.

The short circuit power of the external grid component is chosen 5 MVA (ten times the PV capacity) in order to represent a weak grid according to [8] and facilitate the study of the reactive power impact on the voltage support. Normally, to determine the PV capacity that can be installed in a certain grid, load flow studies are necessary to check the voltage rise at the point of common coupling (PCC). The R/X ratio 0.3 is based on the findings of [9].

The PV generator under normal steady-state operation injects 448.84 kW and 0 kVar, implying power factor (PF) =1 at the point of connection with the LV terminal. The active power is defined by the parameters and the configuration of the PV array (way of interconnection of PV modules), as seen in eq. 1.

$$(V_{MMP_{module}} \cdot 20 \text{ modules}_{series}) \cdot (\mathrm{I}_{MMP_{module}} \cdot 140 \text{ modules}_{parallel}) = \\ = 700 \cdot 641.2 = 448.84\ kW \qquad (1)$$

The V_{MMP} and I_{MMP} are given for the standard test conditions (STC) and all power values are assumed to be at the MPP. The maximum active power operational limit is 475 kW, while the reactive power limits are defined by the capability curve for three different voltage levels (0.95 p.u., 1 p.u. and 1.05 p.u.).

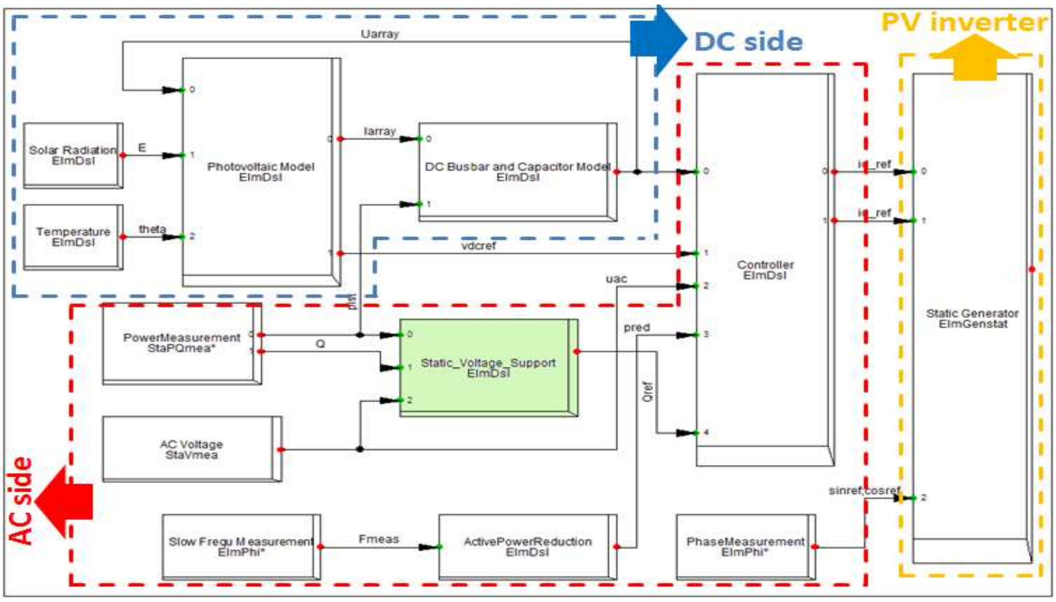


Fig. 3. The control frame of the PV system

The features and the control frame that are integrated inside the PV generator component can be seen in Fig. 3, where a rough demarcation of the basic parts has been made.

The DC side of the model consists basically of the PV array, the DC bus and the capacitor. The most important external factors that affect the power output of the PV array, which are the incoming solar irradiation and the operating temperature, can be controlled by the relevant slots in Fig. 3 by setting parameter events and changing the output values *E* and *theta* respectively. Those values enter the *Photovoltaic Model*, where the array current and the array voltage at MPP are calculated. The algorithm that is used for the calculation of the output values of the array model is written according to the electrical equivalent of the ideal solar cell using temperature correction factors for voltage and current. More details can be found in [10]. As regards the *DC Busbar and Capacitor model*, it represents the DC bus the PV array is connected to and the necessary shunt capacitor. It calculates the voltage across the capacitor, which is the input of the inverter (DC side).

The AC side of the control frame consists of all the basic control requirements for a grid-connected PV system to be compatible with the German grid code for MV. The *Active Power Reduction* slot together with the *Slow Frequency Measurement* device is responsible for the active power curtailment in case of frequency deviations. The *Static Voltage Support*, that seen as shaded slot, is a new addition to the control scheme and is responsible for steady state support by providing reactive power using all the four methods mentioned in Table 1 for the MV grid code. The main *Controller* includes *Reactive Power Support* control in case of voltage dips, written according to the Transmission Code 2007 and the System Service Ordinance SDLWindV. The Controller produces as results the compontents id_ref and iq_ref, which are the reference values of active and reactive power injection respectively. The *Phase Measumerent* device is a Phase Locked Loop (PLL) device built by DIgSILENT that contains an oscillator that is synchronized by being phased-locked to some particular grid power signal (i.e. voltage) and generating an output signal. Normally, as well as in this case, this element is able to measure the phase of a voltage in the system and the frequency (see above Slow Frequency Measurement). The outputs of the main Controller and the PLL enter the *Static Generator*, which is basically the PV gried-tied inverter.

The above control features are explained in depth in [10] through dynamic simulations. Below the basic requirements as mentioned in the introduction part are analyzed.

IV. CONTROL ASPECTS

A. *Active power control*

Active power control refers to active power curtailment, meaning the ability of the generating plant to reduce its power output, as required by the network operator, or even disconnect the PV plant in order to avoid potential dangers regarding the stability of the system and human personnel. The control can be done automatically or manually [11]. As far as the automatic control is concerned, the German grid code for MV requires that the PV generator should reduce its power output when an over-frequency occurs. The over-frequency is defined above 50.2 Hz and the reduction slope is 40% of the last instantaneous value of power (just before 50.2 Hz) per Hz.

The PV model, as it can be seen in Fig. 3 at the AC side, has already a relevant slot for this requirement. In order to investigate the function an over-frequency is created, by changing the *speed* parameter of the external grid component after the 7th second. The result is seen in Fig. 4.

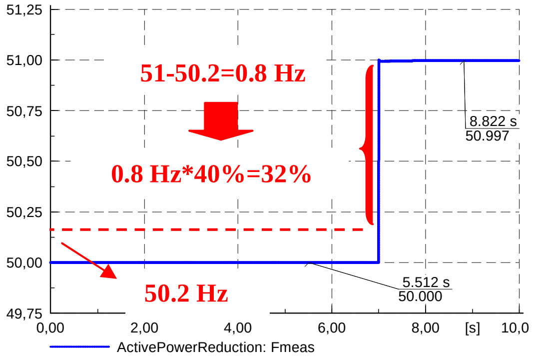


Fig. 4. Over-frequency event

In order for the control function to be in compliance with the grid code, a 32% active power output reduction should be expected since an over-frequency of 0.8 Hz is created. Indeed in Fig. 5 is proved that the generator injects around 32% (31.7%) less active power during the over-frequency. The reduction response is less than 50 ms.

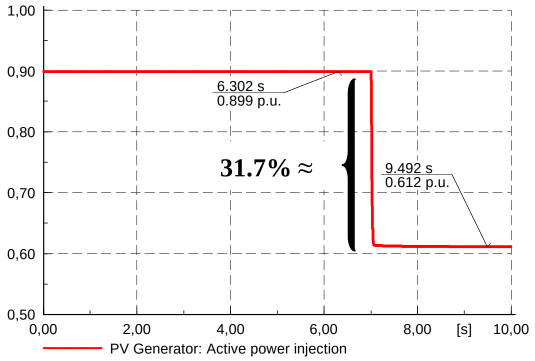


Fig. 5. Active power reduction due to 0.8 Hz over-frequency

B. *Dynamic Voltage Support*

When referring to dynamic voltage support, it simply implies the requirements that a PV system should fulfill under fault conditions and grid disturbances (voltage dips). Furthermore, it defines the system's behavior after the restoration of the fault. These requirements include Fault-Ride-Through (FRT) requirements and reactive current injection.

FRT describes possible scenarios of different voltage dips and how the grid-tied PV system, more specifically the PV inverter, should behave depending on the voltage dip and its duration. The PV inverter should remain connected to the grid for a certain period and if necessary support it by providing reactive current. The possible scenarios are described thoroughly in [11].

As cited before, the model contains a *Reactive Power Support* slot responsible for providing reactive current during voltage dips. To investigate this requirement, four different tests take place. In each test a different voltage dip is simulated for a different duration of time. The tests performed are seen in Table 2.

TABLE 2: TESTS PERFORMED FOR FRT BEHAVIOR

Test	Maximum line-to-line voltage U/U_n	Duration of fault [ms]
1	0	150
2	0.2	550
3	0.5	1000
4	0.8	1500

The tests are designed according to the specific standards for FRT examination in type-2 generating units. Type-2 units are those where no synchronous generator is involved that is directly coupled to the grid. Those standards are found in [12] for generating units and the German grid code. The different voltage dips are achieved by adjusting the fault impendence. All the obtained results are summarized in Table 3, while in Fig. 6 the results of Test 1 are seen, which corresponds to a pure short-circuit fault (100% voltage dip).

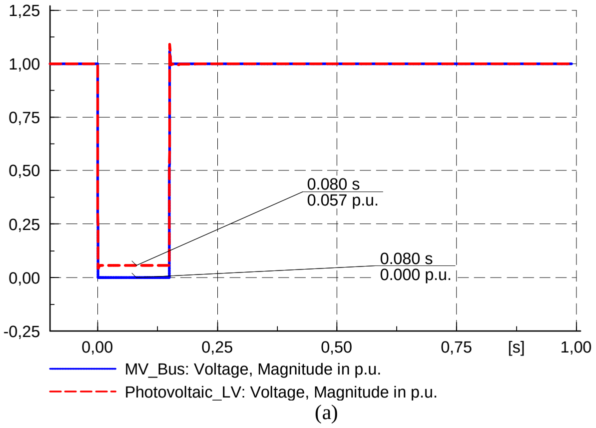
TABLE 3: AGGREGATION OF THE RESULTS OF ALL TESTS

Voltage dip [%]	**Voltage level in the LV bus [p.u.]**	**Injected active power by the PV [kW]**	**Injected reactive power by the PV [kVar]**	**Injected reactive current by the PV [kA]**
100	0.057	0	26.72	0.681
80	0.248	30.54	93.35	0.542
50	0.525	138.15	124.55	0.342
20	0.834	348.35	68.75	0.119

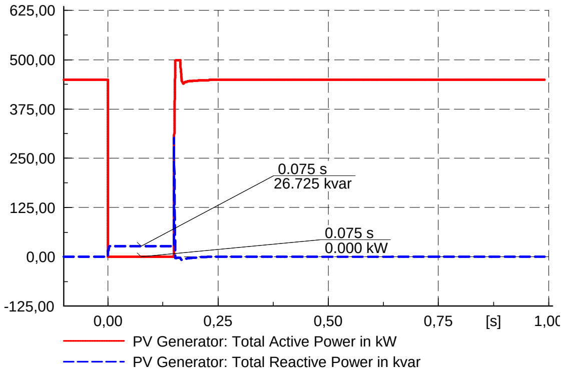
Seeing the results of the above table, the following conclusions can be drawn. Starting with the most expected outcome, when the voltage drop becomes bigger the active power injection of the PV generator is less and in a pure three-phase fault the injected active power is 0. The reason for this reduction of active power is to enhance the ability of the PV generator to provide reactive power for the voltage support. As seen in this case, the method is to reduce slowly the active power injection and increase at the same time the reactive power supply. Another method could have been to reduce at once the active power to zero, below a certain voltage dip (i.e. 70%), and increase the reactive power supply to facilitate the voltage stability.

As far as the reactive current injection and the voltage level at the connection point of the PV generator is concerned, which is the actual purpose of this investigation, it is seen that the reactive current injection is bigger when the voltage dip is bigger, trying to support the voltage until the fault clearance. The voltage at the connection point is never 0 not even for the 100% voltage dip, where the generator remains connected for a maximum of 150 ms (typical operating time for protection relays) providing reactive current. Furthermore, the response time of the controller for injective reactive current is found to be almost instant (less than 30ms), therefore, the results are in accordance with the grid code. The reactive current injection follows eq. 2, where *K* is the droop parameter, which is 1 for this case. However, normally a factor of 2 is used as default, which is equivalent for the behavior of a synchronous generator. The value du_{ac} is the result of $u_{ac/before\ the\ fault} - u_{ac/during\ the\ fault}$.

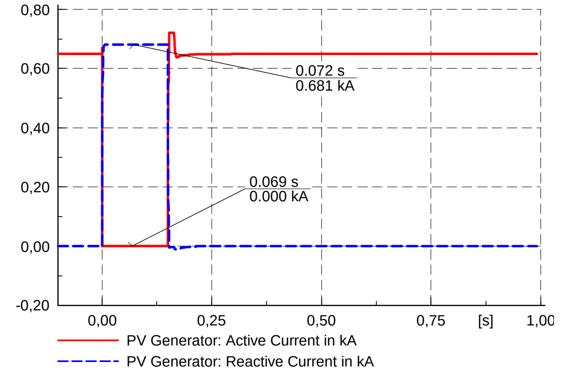
$$i_q = K\left|du_{ac}\right| \qquad (2)$$



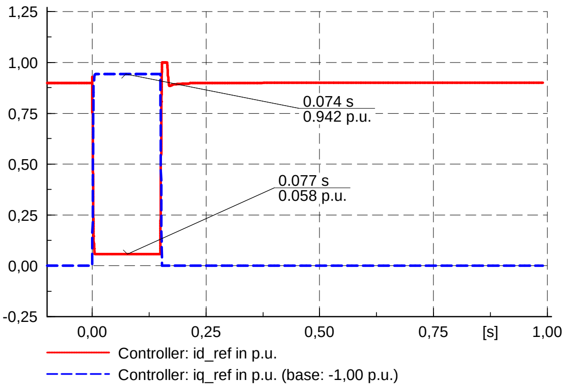
(a)



(b)



(c)



(d)

Fig. 6. FRT results during a pure short-circuit fault: (a) voltage level in LV and MV bus, (b) active and reactive power injection by the PV generator, (c) active and reactive current injection by the PV generator, (d) reference values of the id and iq components of the controller

Finally, the injected reactive power by the generator is dependent on two inversely proportional factors, the voltage level and the reactive current. Thus, the maximum value should be at voltage dip of 50%, which is the case as seen in the Table 3.

The reactive current injection and LVRT requirements are fulfilled in each of the 4 tests that the PV model is examined. The voltage stabilizes almost instantly after the fault clearance ensuring that the PV is capable of dynamic voltage support.

C. *Static voltage support*

One important weakness of the model is the lack of ability to provide static voltage support under normal operation of the grid. The PV system must be able to address small voltage deviations at the point of connection and according to the

German grid code for MV the generator should be able to supply reactive power to maintain the voltage band within steady state operation limits (see Table 1). In order to correct this shortcoming and improve the model, a Q control is proposed, which is seen in Fig. 7.

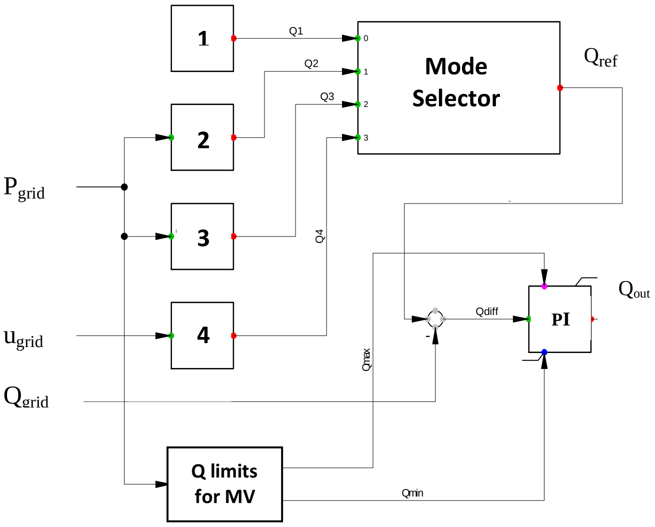


Fig. 7. Proposed Q control

The Q control is designed to operate in four different modes, which are presented in Table 4, depending on the system operator. The necessary input signals are the *active power (P)*, the *reactive power (Q)* and the *voltage (u)* at the connection point of the PV generator (inverter).

TABLE 4: DIFFERENT OPERATING MODES FOR Q CONTROL

Mode selector	**Method of Q supply**
1	Constant Q (based on a set-point value)
2	Constant cosφ (Q based on a set-point value of PF)
3	Function cosφ(P) (Q based on PF, which is dependent on P)
4	Function Q(U) (Q based on voltage)

The controller “reads” the input values and according to the selective mode produces a Q_{ref} value. The mode selection is done by changing the parameter *Mode* from 1 to 4 in the parameter table. The Q_{ref} is then compared with the measured value of reactive power at the connection point, denoted as Q_{grid} in Fig. 7 and the difference (Q_{diff}) passes through a PI controller. The PI block is used to limit the Q_{diff}, in order the controller to provide a reactive power, which is as close as possible to the required Q_{ref} value. The PI controller uses as upper and lower limitation the values produced by the *Q limits for MV* block, which calculates the total maximum and minimum reactive power capability based on the active power at the connection point and Fig. 8.

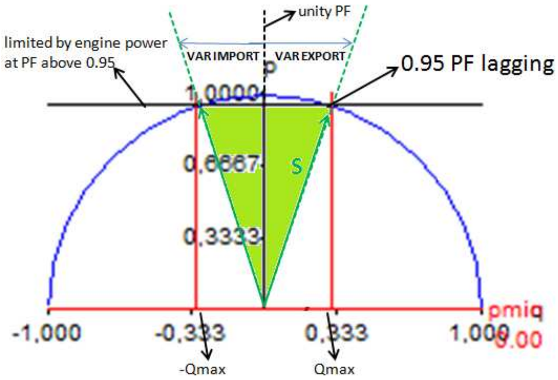


Fig. 8. Q Capability requirements according to MV grid code

The shaded area in the above figure reflects the reactive power capability requirements according to the grid code for MV. The PV inverter should be able to provide reactive power within the area defined by $0.95_{lagging}$ and $0.95_{leading}$ PF.

The final signal from the PI controller (Q_{out}), which is in fact a reactive current component, passes though the main controller and then leads to the PV generator (PV inverter). Inside the main controller the signal is not subjected to further modifications. However, for normal operation and voltage dip bigger than 10% the reactive current injection and subsequently the reactive power is provided by this Q_{out} value. Thus, inside the main controller there is a “switch” that changes between normal and fault operation according to the voltage deviation (voltage drop).

In order to test the effectiveness of the implemented control a parameter event is set, where the active power injection by the static generator is being changed and specifically is being reduced from 450 kW to 250 kW as seen in Fig. 9. That can be the result of solar radiation change by setting a parameter event and changing the E value from Fig. 3. With this test the first three methods of Table 4 are examined.

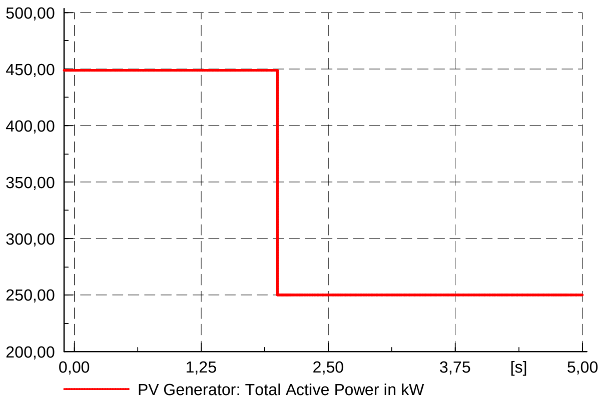


Fig. 9. Active power injection change

The Q controller is set at first to operate in Mode 1, then in Mode 2 etc. The constant Q in Mode 1 is chosen 56 kVar (which gives PF around 0.99, taking into consideration the nominal active power), while the PF in Mode 2 is chosen 0.98. In Fig. 10 the measured values of the reactive power at the connection point and for each method are presented in response to the parameter event.

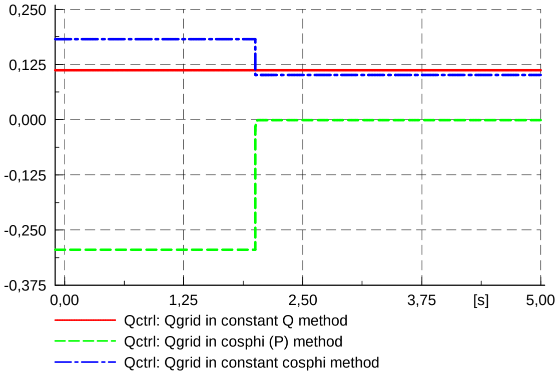


Fig. 10. The measured values of the reactive power at the connection point in each method

The results of the above graph show that when the controller operates in Mode 1, produces a constant value of reactive power based on the given set-point (reference value).

On the other hand, when the controller operates in Mode 2 (constant cosphi) and the active power is reduced at the connection point, the reactive power is reduced as well in order to maintain the PF constant at 0.98. That behavior can be clearly seen in Fig. 11

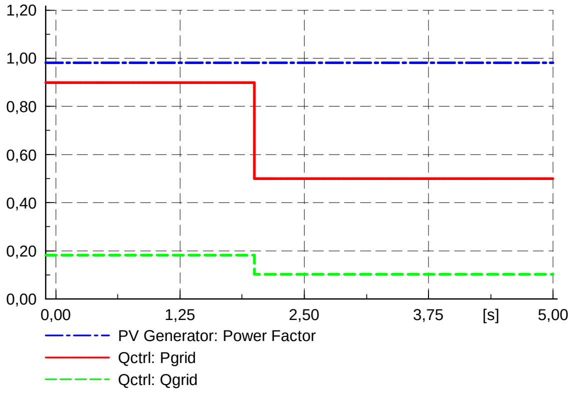


Fig. 11. The behavior of the controller under Mode 2 operation

At last when the controller operates in Mode 3, cosphi (P), the reactive power is supplied by adopting the PF according to the active power change and based on a characteristic that in reality is provided from the network operator. In this case the characteristic is seen in Fig. 12. The PF of course is kept within limits (0.95_{lagging} and 0.95_{leading}).

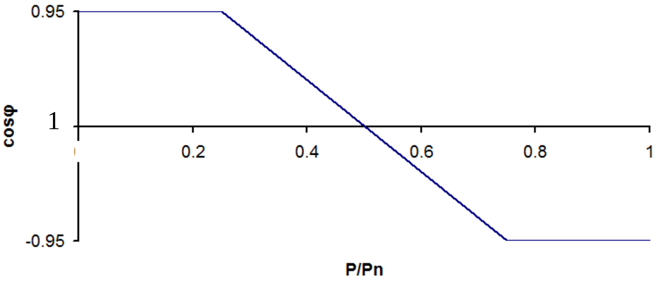


Fig. 12. The characteristic of cosφ (P) of the controller under Mode 2 operation

As far as the last method/mode Q(U) is concerned, a different type of simulation event is set, in which, the voltage level at the connection terminal is being changed as shown in Fig. 13 with the straight line. The response of the controller in this increment of the voltage is to consume reactive power based on a specific droop.

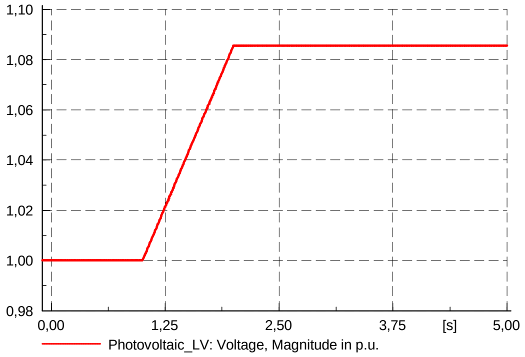


Fig. 13. Voltage change profile in Q(U) method

The marked area in the below Fig. 14 shows that the controller reached its limitations.

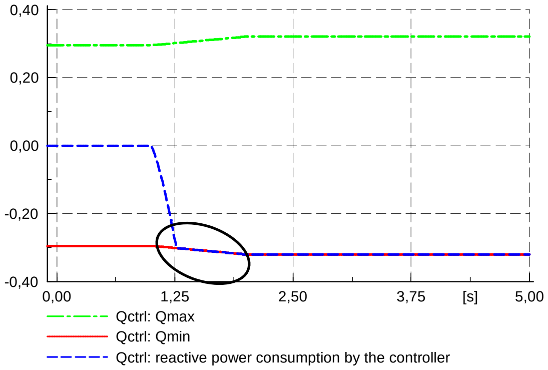


Fig. 14. Reactive power support in Q(U) method

V. CONCLUSIONS AND RECOMMENDATIONS

In this paper important aspects of a generic PV model built by DIgSILENT are examined. The model consists of a static generator with an integrated control scheme. Its static and dynamic behavior is investigated according to the requirements of the German grid code for the MV distribution network.

Active power reduction requirement is effectively adjusted and operates in case of over-frequency events. The FRT requirement is tested under four different voltage dips of different duration each according to [12] for type-2 generating units. The results support the capability of the PV model in question to remain connected when a voltage dip occurs and provide reactive current when is needed according to the grid code. Thus, the grid stability is enhanced at the point of connection since remaining the generator connected is able to provide active power the moment the grid is stabilized without jeopardizing further the grid reliability (e.g. creating frequency problems under excess load conditions, leading to supply failure and even blackouts).

As far as the static voltage support is concerned, initially the model had no relevant control. For this reason, a Q control is implemented capable to operate in four different modes as it is described by the grid code. The controller shows sufficient behavior when changes of active power and voltage take place at the terminal that the generator is connected. The switch between static voltage support and dynamic voltage support in case of a fault is inside the main controller and ensures reactive power support in any occasion.

However, there are still many issues to be tested and improvements to be done in order the model to be able to address a wider range of requirements. Power quality studies and protection requirements are some of those issues. Furthermore and since the model includes an array model, the need of a more adequate PV array model is also necessary since no resistance losses are taken into account for the output values. However, for performing studies to examine the behavior of the network, this improvement is not considered necessary.

Rounding up the conclusions of this paper, in response to the fact that policies and incentives have brought PV market to the fore, attention should be turned to address design and control issues that will encourage a high PV penetration without compromising the stability and normal operation of the power system.

VI. ACKNOWLEDGMENTS

The authors would like to acknowledge the valuable contribution of Stefan Langanke on improving the control scheme of the generic model. His work as regards the Q control has been used in this paper. Stefan Langanke is a member of the Energynautics team working on various topics concerning electrical power supply and integration of renewable energies to the grid.

VII. REFERENCES

[1] Brown M., *"Integrating PV in Local Distribution Systems -Germany-"*, IEA PVPS Task 14 Meeting, Golden, CO, USA, 01.12.2010, available at www.nrel.gov/eis/pdfs/iea_task_14_workshop_braun.pdf , as accessed 25.02.2011

[2] European Commission, *"National Renewable Energy Action Plan in accordance with Directive 2009/28/EC on the promotion of the use of energy from renewable sources"*, Status report of Federal Republic of Germany, European Commission, 30.6.2010

[3] Prognos, Roland, Berger, *"Photovoltaik wird zur tragenden Säule der Energieversorgergung"*, Bundesverband Solarwirtschaft (BSW), picture available at http://www.solarwirtschaft.de/, as accessed 25.06.2011

[4] Borup Uffe, *"Features of modern grid interconnection devices"*, Danfoss, PV ERA NET The Photovoltaic European Research Area Network, available at http://www.pv-era.net/doc_upload/documents/179_5Featuresofmoderngridinterconnectiondevices.pdf , as accessed 27.02.2011

[5] Teodorescu R., Liserre M., Rodriguez P., *Grid Converters for Photovoltaic and Wind Power Systems*, Wiley, United Kingdom, 2011

[6] TransmissionCode2007 – Network and System Rules of the German Transmission System Operators, Verband der Netzbetreiber VDN e.V. beim VDEW, Berlin, 2007

[7] Generators connected to the low-voltage distribution network – Technical requirements for the connection to and parallel operation with low-voltage distribution networks, Verband der Elektrotechnik Elektronik Informationstechnik e.V., VDE, Berlin, August 2011

[8] Alvaro R., *"System aspects of large scale implementation of a photovoltaic power plant"*, Master Thesis, KTH, Stockholm, Sweden, March 2011

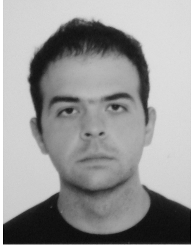
[9] Blazic B., Papic I., "Voltage profile support in distribution networks – influence of the network R/X ratio", *Power Electronics and Motion Control Conference 13th (EPE-PEMC)*, available at *IEEE Xplore*, 30.09.2008

[10] Theologitis I.T., *"Comparison of existing PV models and possible integration under EU specifications"*, Master Thesis, KTH, Stockholm, Sweden, June 2011

[11] Troester E., "New German Grid Codes for Connecting PV Systems to the Medium Voltage Power Grid", *2nd International Workshop on Concentrating Photovoltaic Power Plants: Optical Design, Production, Grid connection*, Darmstadt, Germany, 09-10.03.2009

[12] Fördergesellschaft Windenergie und andere Erneuerbare Energien (FGW e.V.), "Determining the electrical properties of generating units at medium, high and very high voltage grid", Technical Guidelines for generating units, Germany, 15.10.2010

VIII. BIOGRAPHY



Ioannis-Thomas Theologitis was born in Kavala in Greece, on May 26, 1984.

Since 2011, he holds a Master in Sustainable Energy Engineering from the Royal Institute of Technology (KTH) in Stockholm, Sweden. He obtained his Diploma in Electrical Engineering and Computer Engineering from the Democritus University of Xanthi, Greece in 2008. His main focus is on solar energy with experience in photovoltaic technology, modeling, market and policy issues. Since 2011 he works for Energynautics.

Eckehard Tröster was born in Marburg in Germany, on December 7, 1975.

He holds a PhD and a Master of Electrical Engineering from Darmstadt University of Technology, Germany. His research focuses on electrical power systems, renewable energies and electrical machines, especially wind power generators. He has worked as a scientific assistant at the Institute of Renewable Energies, Darmstadt. Since 2007 he works for Energynautics.

Thomas Ackermann is the founder and CEO of Energynautics GmbH a research and consulting company in the area of renewable energy and power systems. He also lectures at Royal Institute of Technology (KTH), School of Electrical Engineering in Stockholm/ Sweden. He holds a degree of a Diplom Wirtschaftsingenieur (M.Sc. in Mechanical Engineering combined with an MBA) from the Technical University Berlin/ Germany, an M.Sc. in Physics from Dunedin University/ New Zealand and a Ph.D. from the Royal Institute of Technology in Stockholm/ Sweden. He is the editor of the book "Wind Power in Power Systems" and Co-editor of the Wind Energy Journal, both published by Wiley.