# A Voltage Regulation System for Distributed Generation

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***Abstract*— Voltage regulation at the point of common coupling (PCC) can increase the penetration level of Distributed Generation (DG) into the distribution network. This paper deals with a voltage regulation algorithm for a grid-connected DG, based on active and reactive power control. A review of different DG reactive power control solutions is made. When the reactive power control is not sufficient to keep the voltage on the appropriate range, an action on the active power must be considered. Two DG operating modes are identified and two switching methods between those modes are compared in respect with DG dynamics. The operating modes switching may induce some oscillations that can be eliminated using an appropriate control algorithm.**

*Index Terms*—distributed generation, power control, reactive power control, voltage regulation.

## I. Introduction

THE purpose of voltage control in distribution networks is to compensate for load variations and events in the transmission system, so that customer supply voltages are kept within certain bounds, settled by European Standards [1].

### A. Voltage Regulation Facilities

The system presented in Fig. 1 illustrates the voltage rise / drop effect and the facilities that can be used to compensate this effect. A distributed generator, G ($P_G$, $Q_G$), together with a local load ($P_L$, $Q_L$) and a reactive compensator ($Q_C$), are connected to the distribution system ($D_S$) via a distribution overhead line with impedance $\underline{Z}$ and an on-load tap changer (OLTC) transformer.

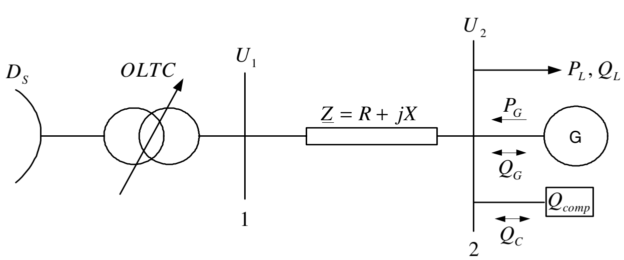


Fig. 1 A simple system illustrating the options for voltage rise effect compensation.

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The voltage drop value along the line is given by:

$$\Delta U = U_1 - U_2 = \frac{R(-P_G + P_L) + X(\pm Q_G + Q_L \pm Q_C)}{U_2} \qquad (1)$$

We can notice from (1) what are the facilities that can be used for the end bus voltage regulation:

- 1) voltage control by the OLTC;
- 2) compensator reactive power control;
- 3) DG reactive power control;
- 4) DG active power control.

These four main control strategies are quantified in [2]:

*1) Voltage control by OLTCs*

Nowadays, in France, voltage control in distribution networks is primarily carried out by OLTCs. Each of those devices is able to regulate the voltage of the secondary side of a transformer at the substations level. The control is discrete-valued, typically with steps of 1-3 %. OLTC control is presently based on a local voltage measurement in each substation.

A typical French distribution network is shown in Fig. 2. It is only composed of the Low Voltage (LV) and Medium Voltage (MV) networks.

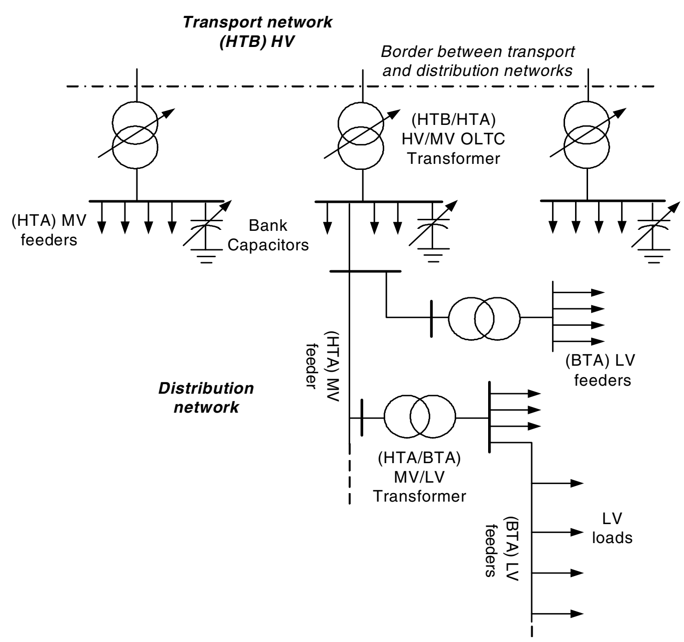


Fig.2 Typical structure of a French distribution system.

There is normally no coordination of OLTCs in different branches of the network. Clearly, the voltage rise effect in

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distribution networks with DG can be controlled by OLTCs (by reducing the voltage at times of high generation output). However, the present voltage control strategy is designed for passive networks with strictly unidirectional power flows.

*2) Reactive power management*

In France, capacitor banks are used for reactive power control. This control is centralized at the power substations level [3].

*3) DG reactive power control*

Absorbing reactive power can be very beneficial in controlling the voltage rise effect, especially in weak overhead networks with DG. Furthermore, an increase of the DG injected active power can be realized in this way. However, the amount of the reactive power that can be consumed by the DG is limited by the regulatory texts.

*4) Active power generation curtailment*

The developer of DG schemes may find it profitable to curtail some of the DG output for a limited period if that allows the connection of a higher capacity generator. This may be particularly attractive if the probability of the coincidence of high generation output with low network load condition is low.

### *B. Application of voltage regulators*

In the context of the voltage rise effect, minimum load - maximum generation conditions are usually critical for the amount of generation that can be connected. However, it may also be necessary to consider maximum load – maximum generation conditions. This is because, the use of OLTC transformers to reduce the voltage on the feeder where the generator is connected, may produce an unacceptably low voltage on adjacent feeders that supply load. In this case it may be beneficial to separate the control of voltage on feeders that supply load, from the control of voltage on feeder to which the generator is connected. This can be achieved by the application of voltage regulators on appropriate feeders.

Different type of DG control in order to regulate the voltage at theirs connecting terminals can be met in literature. A few of those papers are reviewed thereafter.

In [4], Kojovic shows that DG output voltage regulation can be achieved using the reactive power setting. However, this regulation may not be sufficient to control excessive voltages. In these cases, voltage regulators could provide voltage regulation. When DG is connected to distribution lines, voltage control at the point of common coupling (PCC) may be optimized by a slight reduction of source voltage; controlling reactive power; adjusting reactive power to meet the nearby load requirements; and operating the generator in constant voltage mode.

Paper [5] shows that the coordination between DG outputs and OLTC tap controls is a necessity in order to allow higher levels of distributed resources. Otherwise, power injection levels can be severely limited if substation voltage is kept constant by the OLTC transformer.

Reference [6] proposes a control method to let dispersed power sources participate in voltage control and primary frequency control. This method is based on independent control of active and reactive current of the power electronic interface, within the limits imposed by the prime mover and the converter rating.

A hybrid control algorithm of the synchronous generator based DG, that combines automatic voltage and power factor control has been presented in [7] and compared to line voltage rise / drop compensation.

The paper [8] proposes one possibility of developing new structures of control systems for inverter interfaced distributed generators, which exploits the fast response of power electronics' devices to ensure the correct operation of the sources in all the possible operating condition without interfering with the existing system.

A French patent [9] dealing with the installation of a grid-connected DG voltage regulation device into a distribution network, was deposed in 2001. The principle of DG controls in order to regulate the voltage at the PCC with the distribution network is described.

### *C. French regulatory for DG interconnection*

The connection of DG plants to this distribution network is governed by French regulatory texts [10], [11] in accordance with voltage level at the PCC. Therefore, the control of those DG units must be made in respect with those settlements.

Table I gives the voltage level at the PCC as a function of the size in power of the generating plants.

TABLE I
VOLTAGE LEVELS AT THE CONNECTION POINT

| Network | Voltage limits | Effective levels | Power limit |
|---|---|---|---|
| LV | LV (single phase) | 230 V | P ≤ 18 kVA |
| | LV (three phases) | 400 V | P ≤ 250 kVA |
| MV | 1 kV < U ≤ 50 kV | 15 kV, 20 kV | P ≤ 12MW |
| HV | 50 kV < U ≤ 130 kV | 63 kV, 90 kV | P ≤ 50 MW |
| | 130 kV < U ≤ 350 kV | 150 kV, 225 kV | P ≤ 250 MW |
| | 350 kV < U ≤ 500 kV | 400 kV | P > 250 MW |

Regarding the voltage at the connection point and the DG reactive power control, the following constraints are imposed:

- Generating plants connected to the LV grid must not consume reactive power.
- Generating units connected to MV network and with a power less than 1 MW shall be able to produce a reactive power up to 40 % of their apparent nominal power (Sn).
- Generating units with a power between 1 and 10 MW shall be able to produce a reactive power up to at least 50 % of Sn and to consume a reactive power of 10 % of Sn. Within their reactive power generation and consumption capabilities, they shall be able to adjust the voltage level to a certain extent.
- Generating plants with an installed power larger than 10 MW shall be equipped with a voltage control system. Each unit must be able to produce up to at least 60 % of Sn and to consume at least 20 % of Sn.

As for the induction generators, capacitor banks connected to either the producer installations or the HV/MV substation provide their reactive power needs, as well as required additional reactive power generation. The reactive power produced by the capacitor banks shall not exceed 0.4 Sn.

In the following part, we propose a voltage regulation system for electronic interfaced grid-connected DG, based on active and reactive power control. Two control algorithms will be compared in accordance with DG dynamics.

## II. DG Voltage Regulation by Active and Reactive Power Control

The main objective of the DG is to produce active power and inject it into the grid. The DG administrator provides an active power set signal ( $P_{REF\_EXT}$ ) in respect with a technical-economic criteria production plan that intends to optimize the plant profitability.

There can be some cases when this plan cannot be respected due to load variations in the distribution network at the risk of voltage rise beyond the admissible borders. In those cases, the DG must begin to consume reactive power at a first time until the acceptable limits are reached. At a second time, the DG must decrease their output generation. The DG will operate in voltage-regulated mode. Thereafter, we will give details about those two main voltage-regulating facilities.

### A. Voltage regulating by DG reactive power control

*1) Voltage regulating principle*

The Fig. 3 shows the principle of the reactive control. A linear slope with a dead-band ( $\varepsilon$ ) is used to regulate the voltage at the output of DG.

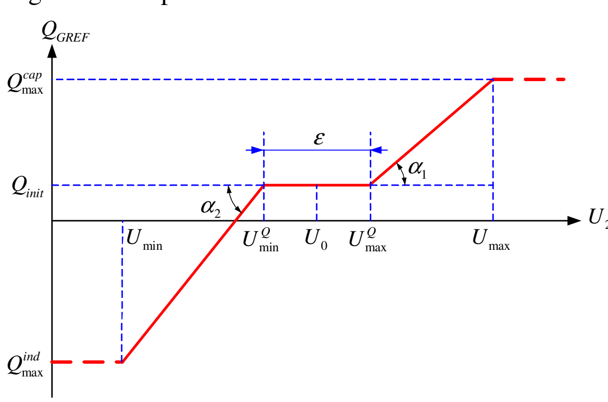


Fig. 3 DG reactive power control low in respect with PCC voltage value.

The DG reactive power boundary values ( $Q_{\max}^{cap}$ , $Q_{\max}^{ind}$ ), can be fixed in a definitive manner or they can fluctuate in function of the DG active power generation according to different variation lows. In this last case, the two slopes will continuously be re-actualized. For this control strategy, we can identify the following regulating parameters:

- $U_0$, ε, $Q_{init}$ : dead-band parameters;
- $KQ_1$, $KQ_2$: reactive power slopes with $KQ_1 = \tan\left(\alpha_1\right)$ $KQ_2 = \tan\left(\alpha_2\right)$.

The two control slopes are determined according to the voltage regulation interval and the reactive power boundary values as following:

$$\begin{aligned} KQ_1 &= \tan\left(\alpha_1\right) = \frac{Q_{\max}^{cap} - Q_{init}}{U_{\max} - U_{\max}^{Q}} \\ KQ_2 &= \tan\left(\alpha_2\right) = \frac{Q_{init} - Q_{\max}^{ind}}{U_{\min}^{Q} - U_{\min}} \end{aligned} \tag{2}$$

The DG reactive power set point is calculated in function of the PCC voltage value using the next algorithm:

$$Q_{GREF} = \begin{cases} Q_{\max}^{ind};\ \text{for } U_2 > U_{\max} \\ Q_{init} + \left(U - U_{\max}^{Q}\right) KQ_1;\ \text{for } U_{\max} \ge U_2 \ge U_{\max}^{Q} \\ Q_{init};\ \text{for } U_{\max}^{Q} > U_2 > U_{\min}^{Q} \\ Q_{init} - \left(U_{\min}^{Q} - U\right) KQ_2;\ \text{for } U_{\min}^{Q} \ge U_2 \ge U_{\min} \\ Q_{\max}^{cap};\ \text{for } U_2 < U_{\min} \end{cases} \tag{3}$$

*2) Borders determination*

As we have said, the DG reactive power boundary values can fluctuate in function of the DG active power generation according to the next variation lows:

*a) Constant reactive power*

$$Q_{GREF} = Q_{\max}^{cap} = \sqrt{S_{GN}{}^2 - P_{GN}{}^2}\ , \tag{4}$$

and

$$Q_{GREF} = Q_{\max}^{ind} = -\sqrt{S_{GN}{}^2 - P_{GN}{}^2} \tag{5}$$

with: $S_{GN}$ - DG rated apparent power; $P_{GN}$ - DG rated power.

*b) Constant apparent power*

$$Q_{GREF} = Q_{\max}^{cap} = \sqrt{S_{GN}{}^2 - P_{GREF}{}^2} \tag{6}$$

and

$$Q_{GREF} = Q_{\max}^{ind} = -\sqrt{S_{GN}{}^2 - P_{GREF}{}^2} \tag{7}$$

with $P_{GREF}$ - active power set point.

*c) Constant power factor*

$$Q_{GREF} = Q_{\max}^{cap} = \left|P_{GREF}\right| \sqrt{\frac{1}{\left(\cos\varphi_N^{cap}\right)^2} - 1} \tag{8}$$

and

$$Q_{GREF} = Q_{\max}^{ind} = -\left|P_{GREF}\right| \sqrt{\frac{1}{\left(\cos\varphi_N^{ind}\right)^2} - 1} \tag{9}$$

with $\cos\varphi_N^{ind}$ / $\cos\varphi_N^{cap}$ - DG rated inductive / capacitive power factors. The DG rated inductive / capacitive power factors are limited by regulatory text [10], [11]. Beyond those limits, the DG output voltage must be regulated by active power control. A parameter “s” is used for strategy algorithm selection as in Table 2.

TABLE II
Strategy Algorithm Selection

| “s” parameter value | Q control strategy |
|---|---|
| 1 | Constant reactive power |
| 2 | Constant apparent power |
| 3 | Constant power factor |

The next figure embodies the DG reactive power control block diagram. The response time of the DG reactive power is generally very fast due to the utilization of the power electronic devices for interconnection with the distribution network. The DG dynamics are represented by a first order transfer function (time constant $\tau_Q$ ).

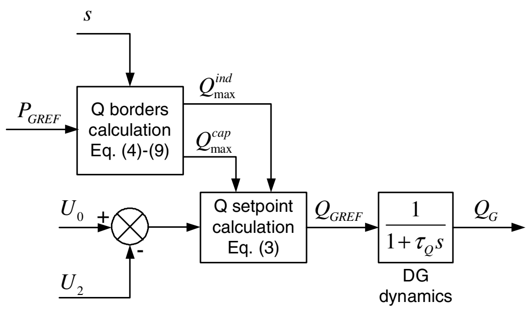


Fig. 4 DG reactive power control block diagram

## B. Voltage regulating by DG active power control

When the reactive power borders are reached, the DG must pass to active power control in order to hold the voltage in an appropriate range. Using a slope based control strategy is not possible anymore because the voltage must been controlled in a very precise way in order to avoid the overrange. Therefore, a regulation loop with an integral action controller is used. The regulation loop block diagram is shown in Fig. 5. The loop dynamic is chosen according to the DG dynamics, and to the network characteristics. A linear model of the distribution system (see APPENDIX), with a time constant ( $\tau_P$ ), which represents the DG dynamics, is used to calculate the controller parameters.

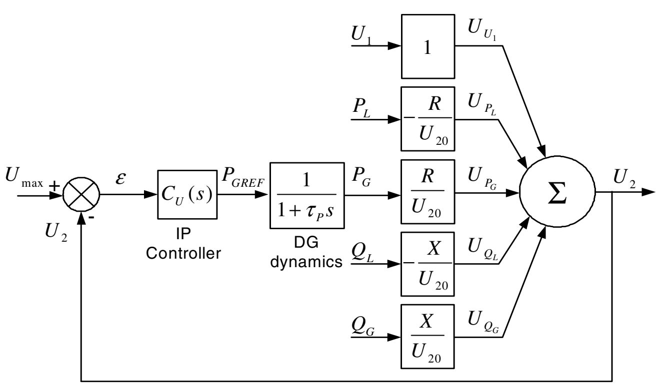


Fig. 5 Regulation loop block diagram.

# III. DG Operating Modes

Up to now, we have presented the principles of voltage regulation by DG reactive power and then by active power control. Thereafter, we can define two DG operating modes:

## A. Mode 1: Reactive power control

If the voltage value is into the dead band interval, no regulation control is active. If the PCC voltage value is between the legal limits ( $U_{min}, U_{max}$ ), a reactive power slope regulation control is activated. The DG active power reference value ( $P_{REF\_EXT}$ ) is given by the DG administrator.

## B. Mode 2: High limit voltage regulation

In this operating mode, the DG reactive power has reached the maximum admissible value ( $Q^{ind}_{max}$ ) and the IP controller based DG active power control is activated. A new DG active power set point ( $P_{REF\_CONT}$ ) is obtained at the output of the regulator.

*Remark*: In this case, the reactive power control algorithm (respectively the borders calculation) is still in service.

# IV. Transitions Between the Two Modes

Thereafter, we will compare two different solutions for the transition between the two operating modes. For this purpose, the simple test system presented in Fig. 1 is used. The compensator device is removed from the system and the voltage at the bus 1 is kept constant by the OLTC during the simulations. Two load variation profiles are used to illustrate the transitions between the operating modes of the DG (see Fig. 9 a) and Fig. 10 a)). All simulations parameters are reviewed in the APPENDIX.

## A. Solution no. 1

The first solution consists in validating one of the operating modes according to the measured value of the voltage at the PCC. Therefore, the measured voltage at the PCC ( $U_2$ ) is compared with the imposed limit value ( $U'_{max}$ ), which is deliberately chosen smaller than the value imposed by the regulatory papers ( $U_{max}$ ), in order to avoid the overrange. A hysteresis block is used to avoid the oscillations around the imposed limit. Fig. 6 shows the diagram block of the DG active power control for this first solution.

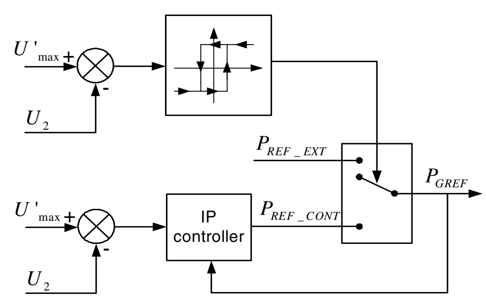


Fig. 6 First solution for the operating modes switching

On the switching time, the output of the corrector is initialized with the actual DG active power set point ( $P_{REF\_EXT}$ ), in order to avoid any discontinuity for $P_{GREF}$ .(see Fig 9, e).).

When voltage value falls under the hysteresis block lower limit, a transition between the operating modes occurs, and the DG active power set point is imposed by the external signal ( $P_{REF\_EXT}$ ). If the dynamic of the voltage regulation closed loop is infinite, the algorithm will never turn to mode 1.

The commutation between the two modes depends on the dynamic if the whole system and also the choice of hysteresis band. Furthermore, discontinuity on the active power reference ( $P_{GREF}$ ) occurs when the controller is disabled since the output of the controller ( $P_{REF\_CONT}$ ) is not equal to the external reference ( $P_{REF\_EXT}$ ).

This may induce oscillations, in some cases, when the load is increasing as noticed on Fig 10. e).

*B. Solution no. 2*

We propose another solution to trip between both modes. This solution is not based any more on the voltage but on the comparison between the output of the controller, which is permanently validated, and the external reference of the active power.

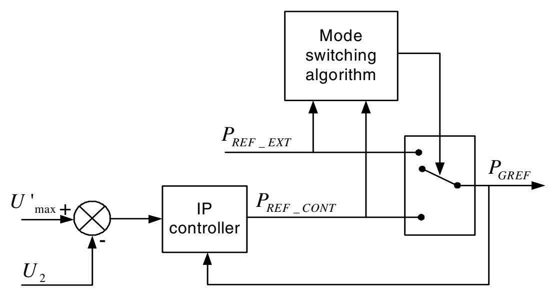


Fig. 7 Second solution for the operating modes switching

When the voltage is under the high limit, the active power set point ( $P_{GREF}$ ) is the external one ( $P_{REF\_EXT}$ ) The output calculated by the controller ( $P_{REF\_CONT}$ ) is then higher than the external reference since the voltage reference is never reached.

In these conditions, $P_{REF\_CONT}(k)$ value is imposed to $P_{REF\_EXT}(k)$ for each moment of time $kTs$ ( $Ts$ : sample time). This supposes to recalculate the integral part of the IP controller. To illustrate this proposition, we remind the basic digital algorithm of a IP controller :

$$\begin{aligned} &P_{REF\_CONT}(k) = K_1\left(U'_{\max} - U_2(k)\right) + I(k-1) - K_2U_2(k) \\ &P_{REF\_CONT}(k) = I(k) - K_2U_2(k) \end{aligned} \tag{10}$$

This algorithm may be represented by a block diagram as in the next figure:

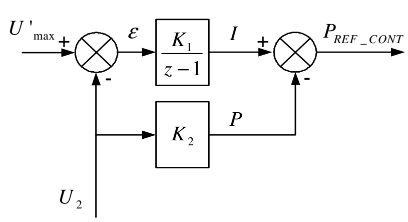


Fig. 8 Numerical implementation of a IP controller.

The output of the controller is recalculated in order to set it to the external reference.

$$P_{REF\_CONT}(k) = P_{REF\_EXT}(k) \tag{11}$$

This supposes to recalculate the integral part of the controller :

$$I(k) = P_{REF\_EXT}(k) + K_2U_2(k) \tag{12}$$

This is an anti wind-up algorithm with a variable output saturation.

Since the output of the controller is forced to follow the external reference, the comparison between both values allows us to detect the moment when the voltage $U_2$ is higher than the limit value $U'_{\max}$. We demonstrate now this proposition.

At time moment $(k+1)Ts$ , $P_{REF\_CONT}(k+1)$ is calculated:

$$\begin{aligned} P_{REF\_CONT}(k+1) = K_1\left(U'_{\max} - U_2(k+1)\right) + \\ + I(k) - K_2U_2(k+1) \end{aligned} \tag{13}$$

We calculate then the difference between: $P_{REF\_CONT}(k+1)$ and $P_{REF\_EXT}(k)$ , which is the same as $P_{REF\_CONT}(k)$ :

$$\begin{aligned} &P_{REF\_CONT}(k+1) - P_{REF\_EXT}(k) = \\ &= K_1\left(U'_{\max} - U_2(k+1)\right) + I(k) - \\ &-K_2U_2(k+1) - I(k) + K_2U_2(k) \end{aligned} \tag{14}$$

It comes :

$$\begin{aligned} &P_{REF\_CONT}(k+1) - P_{REF\_EXT}(k) - K_2\Delta U(k) = \\ &= \left(K_1 + K_2\right)\left(U'_{\max} - U_2(k)\right) \end{aligned} \tag{15}$$

With : $\Delta U(k) = U'_{\max} - U_2(k)$ .

If we supposes that $K_2\Delta U(k)$ is negligible, the comparison on $P_{REF\_CONT}(k)$ and $P_{REF\_EXT}(k)$ gives the sign of $U'_{\max} - U_2(k)$ and so, it may be used for the operating mode switching from mode 1 to mode 2.

On the reverse, the switching from mode 2 (voltage regulation) to mode 1, is also activated by the comparison between both active power references. As soon as the output of the controller becomes higher than the external reference, the reference $P_{GREF}$ is set to $P_{REF\_EXT}$. So there is no discontinuity on the power set point and the switching moment does not depend on parameters of the control part (hysteresis band, closed loop dynamic …).

On Fig 9 e) we can notice that the DG active power set point behaviour is nearly the same for a switching from mode 1 to mode 2 but the second solution is better for switching from mode 2 to mode 1 since some oscillations may be noticed with the first solution (Fig 10 e).).

We observe also on Fig 9 d), the evolution on reactive power in respect with the evolution of voltage.

*Remark*: The strategy chosen for the reactive power control in the DG operating mode2 is the first one (constant reactive power control: s = 1).

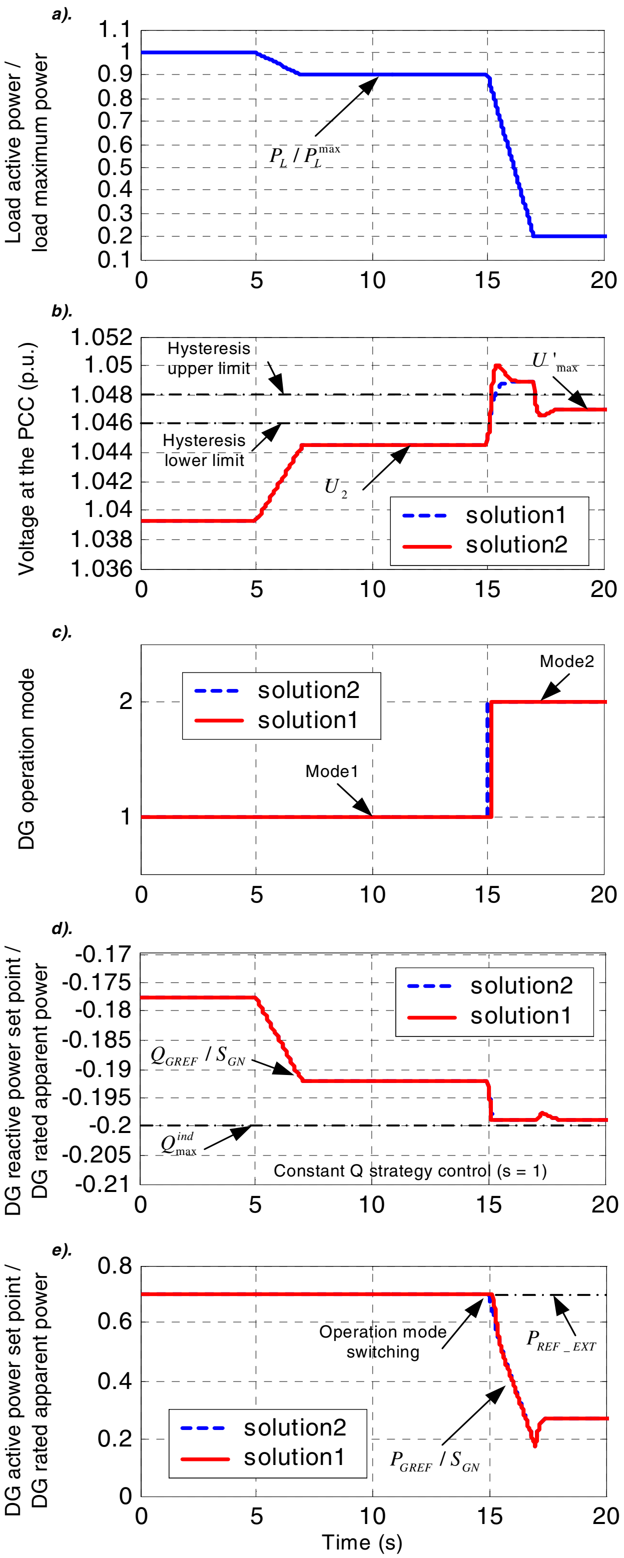


Fig. 9 Simulation results : a) load active power variation; b) voltage at the PCC; c) operating mode of the DG; d). DG reactive power set point; e). DG active power set point.

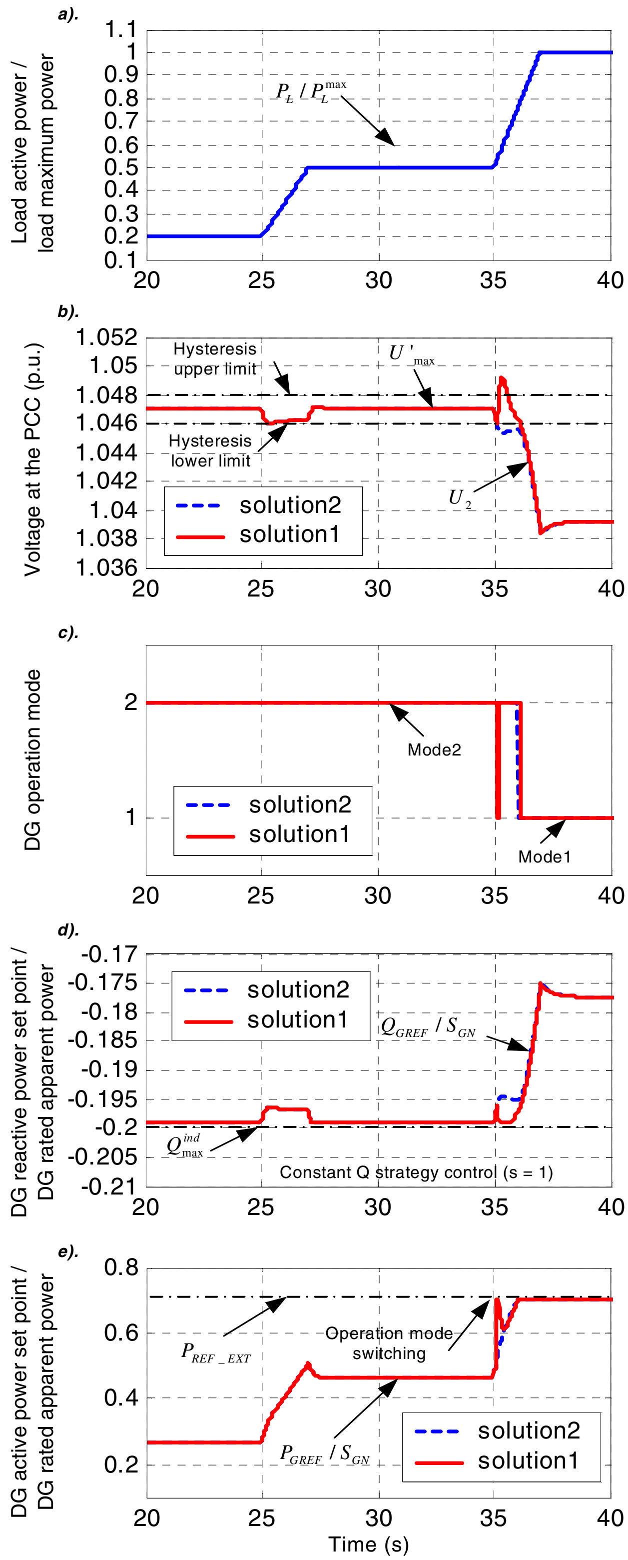


Fig. 10 Simulation results : a) load active power variation; b) voltage at the PCC; c) operating mode of the DG; d). DG reactive power set point; e). DG active power set point.

## V. Conclusion

The introduction of DG in the distribution network can be a source of overvoltage problems for the electric power system if care is not exercised in the design, control and interface of the DG equipment. To overcome the voltage problems at the PCC, several solutions for the DG reactive power control are proposed. The choice between them must be adapted to the legal settlements that are very restrictive nowadays. The efficiency of the DG reactive control on the voltage regulation is limited by the X/R ratio. Therefore, we have to investigate another facility to regulate the voltage: the DG active power curtailment.

We demonstrate that a very simple control low, which compares in real time the external reference of the DG power with the output of a voltage controller, is well appropriated to switch between the two DG operating modes. Furthermore, this control low optimize in real time the active power generated by the DG in respect with the voltage limits.

A more realistic model for the DG will be considered in a future work. We will also consider the interaction between several voltage regulated DGs interconnected on the same distributed network.

## VI. Appendix

### *A. Linear model of distributed network.*

We have the following expression:

$$U_1 - U_2 \cong \frac{RP + XQ}{U_2} = \frac{R\left(P_L - P_G\right) + X\left(Q_L - Q_G\right)}{U_2} \quad \text{(A.1)}$$

The next hypotheses are made:

- $P, Q$ are independent variables;
- $R, X$ are constant.

Therefore we can write:

$$U_2 \cong U_1 - \frac{RP + XQ}{U_{20}} = U_{U_1} + U_{P_L} + U_{P_G} + U_{Q_L} + U_{Q_G} \quad \text{(A.2)}$$

with: $U_{U_1} = U_1$, $U_{P_L} = -\dfrac{RP_L}{U_{20}}$, $U_{P_G} = \dfrac{RP_G}{U_{20}}$,

$U_{Q_L} = -\dfrac{XQ_L}{U_{20}}$, $U_{Q_G} = \dfrac{XQ_G}{U_{20}}$,

where: $U_{20}$ - bus 2 initial voltage value.

### *B. Simulation parameters*

The parameters of the simulations are reviewed thereafter:

TABLE III
PARAMETERS OF THE SIMULATIONS

| | |
|---|---|
| Base voltage | $U_{base} = 20\,(kV)$ |
| Line characteristics | $U_1 = 1.05\,(p.u.)$ ; $R = 4.4$ (ohms) ; $X = 3.6$ (ohms) |
| Load characteristics | $P_L^{\max} = 4.5\,(MW)$ ; $PF_L = 0.9$ |
| DG characteristics | $S_{GN} = 9.46\,(MVA)$ ; $\cos\varphi_N^{ind} = 0.98$ ; $\cos\varphi_N^{cap} = 0.8$ |
| DG Q control parameters | Dead band: $\varepsilon = 0$ (p.u.) ; $U_0 = 0.975$ (p.u.) ; $Q_{init}$ / $S_{GN} = 0$ ; $U_{\min} = 0.903$ (p.u.) ; $U_{\max} = 1.047$ (p.u.) ; s = 1 |
| DG P control parameters | $U'_{\max} = 1.047$ (p.u.) ; $K_P = 40$ ; $T_I = 0.32$ ; $T_s = 0.01$ (s) |

## VII. Acknowledgment

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LIST OF SYMBOLS

| | |
|---|---|
| *DG characteristics* | |
| $S_{GN}$ | DG rated apparent power (MVA) |
| $P_{GN}$ | DG rated active power (MW) |
| $\cos\varphi_N^{ind}$ , $\cos\varphi_N^{cap}$ | DG rated inductive / capacitive power factors |
| $\tau_P$ , $\tau_P$ | Time constants representing the DG dynamics |
| *Load characteristics* | |
| $P_L^{\max}$ | Load active power maximum value (MW) |
| $PF_L$ | Load power factor |
| *DG reactive power control characteristics* | |
| $Q_{GREF}$ | DG reactive power set point (p.u.) |
| $s$ | DG Q control strategy algorithm selection parameter |
| $\varepsilon$ | Dead-band (p.u.) |
| $U_{\min}^{Q}, U_{\max}^{Q}$ | Dead-band borders (p.u.) |
| $Q_{\max}^{ind}, Q_{\max}^{cap}$ | DG reactive power borders (p.u.) |
| $Q_{init}$ | DG reactive power set-point value when the voltage at the connection point is between the dead-band borders (p.u.) |
| $KQ_1$, $KQ_2$ | DG reactive power slopes |
| $U_{\min}, U_{\min}$ | Voltage limits imposed by the regulatory papers |
| *DG active power control characteristics* | |
| $U'_{\max}$ | Voltage set-point (p.u.) |
| $K_P, T_I$ | IP controller parameters |
| $T_S$ | Sample time (s) |

## IX. BIOGRAPHIES

**Emanuel – Florin Mogos** received his MSc degree in electrical engineering from the University "Politehnica" of Bucharest (UPB), Romania in 2000. He is currently working on a PhD on the integration of the Dispersed Generation into LV grids at the "Laboratoire d'Electrotechnique et d'Electronique de Puissance de Lille (L2EP)". He is involved in the "Futurelec 1" project in the setting of "Centre National de Recherche Technologique (CNRT)" of Lille.

**Xavier Guillaud** (M' 2002) received a PhD in electrical engineering in 1992 from the University of Science and Technology of Lille (USTL). He joined the Laboratory of Electrical Engineering and Power Electronic of Lille in 1993. Currently professor in EC Lille, his main topics of interest concern firstly the modeling and control of power electronics systems. In the last few years, he interested himself into integration of dispersed generation system in electrical grid and specially those where power electronic converter is involved in.