Voltage control and power flows optimization

Link to explanations, examples and the selection list for indicated fields, please refer to document "Use Case Description draft ver0.55"

<http://www.cen.eu/cen/Sectors/Sectors/UtilitiesAndEnergy/SmartGrids/Pages/default.aspx>

Version of Template: 0.55, Sept 2011

# Description of the Use Case

* + *General*
  + *Name of Use Case*

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| ***ID*** | ***Domain*** | ***Name of Use Case*** | ***Level of Depth***  *Cluster, High Level Use Case, Detailed Use Case* |
| WGSP-0200 | Distribution Grid Management/Microgrid | Voltage control and power flows optimization | High-level Use Case |

* + *Version Management*

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| ***Changes / Version*** | ***Date*** | ***Name  Author(s) or Committee*** | ***Domain Expert*** | ***Area of Expertise / Domain / Role*** | ***Title*** | ***Approval Status***  *draft, for comments, for voting, final* |
| 1.0 | 12-12-2011 | Carlo Tornelli, Gianluigi Proserpio â€“ RSE SpA | Primary | Distribution Grid Management and Substation Automation | Researcher | - |

* + *Basic Information to Use Case*

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| ***Source(s) / Literature*** | ***Link*** | ***Conditions (limitations) of Use*** |
| Enhance Local Power Quality | FINS-0019 | - |
| Dynamic Control of Active Components | FINS-0003 | - |
| Volt Var control and LV state estimation | ON-0017 | - |
| Voltage stability in a low voltage area | MOMA-0001 | - |
| Telecontrol / Telecommand | FNN-0004 | - |
| Reactive Power | DKE-0003 | - |
| Frequency Response | DKE-0001 | - |
| Voltage control on MV grids with high DER penetration | RSE-0001 | - |
| A Distribution Grid Voltage Control | ENNET-0015 | - |

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| ***Relation to Higher Level Use Case*** | |
| ***Cluster*** | ***Higher Level Use Case*** |
|  | Fault location, isolation and system restoration (FLIR) |

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| ***Maturity of Use Case*** *- in business operation, realized in demonstration project, realised in R&D, in preparation, visionary* |
| Realized in Research and Development project |
| ***Prioritisation*** |
| Needed for countries with high DER penetration on distribution grid |
| ***Generic, Regional or National Relation*** |
| Generic |
| ***View*** *- Technical / Business* |
| Technical |
| ***Further Keywords for Classification*** |
| Voltage and Var Control, DER management |

* + *Scope and Objectives of Use Case*

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| ***Scope and Objectives of Function*** |
| This function optimizes the voltage profile and power flows to maintain stable voltage at customer site in a defined area of the distribution grid with distributed generators, flexible loads and other deployed power equipments.The main optimization criteria can be extended to supply ancillary services to the grid at upper level and pursue operating costs minimization. Normal 0 21 false false false MicrosoftInternetExplorer4 /\* Style Definitions \*/ table.MsoNormalTable {mso-style-name:"Normale Tabelle"; mso-tstyle-rowband-size:0; mso-tstyle-colband-size:0; mso-style-noshow:yes; mso-style-parent:""; mso-padding-alt:0cm 5.4pt 0cm 5.4pt; mso-para-margin:0cm; mso-para-margin-bottom:.0001pt; mso-pagination:widow-orphan; font-size:10.0pt; font-family:"Times New Roman"; mso-ansi-language:#0400; mso-fareast-language:#0400; mso-bidi-language:#0400;} |

* + *Narrative of Use Case*

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| ***Narrative of Use Case*** |
| ***Short description*** *- max 3 sentences* |
| The function monitors the grid status in the controlled area from field measurements and computes optimized set points for DERs, flexible loads and other deployed power equipments. Voltage profile optimization is reached by controlling reactive and active power injection by distributed generators and energy storages, and setting On Load Tap Changers (OLTC), voltage regulators, switched capacitor banks and Flexible AC Transmission System (FACTS) devices. Costs of control actions and load/generation forecasts in the area can be taken into account to select the appropriate control strategy. |
| ***Complete description*** |
| Voltage profile and power flows in active distribution grids are changing dynamically, mainly because of the stochastic production of renewable sources. The power injected by distributed generators can overload feeder segments or lead the voltage beyond the limits in some parts of the grid. In order to guarantee the correct voltage value at each customer site, the voltage profile of the distribution grid is continuously monitored and optimized using the available network flexibilities.   Considering an area of the distribution grid, the optimization function computes the optimal settings of controllable generators, storage units, flexible loads and other deployed power equipments (e.g. tap changers, switched capacitor banks) in the controlled area. Costs of control actions and load/generation forecasts in the area can also be taken into account in order to select the appropriate control strategy.  The optimization function can be implemented in a delocalized control center for the selected area. Considering the hierarchical architecture of distribution grids, control areas may be Medium Voltage (MV) or Low Voltage (LV) sections of the grid, typically underlying a primary (HV/MV) or secondary (MV/LV) substation and having one point of common coupling with a distribution bus or an upper level grid. In this case, the optimization can be performed by the Substation Control System.   At border of the control zone the function can manage the area as a technical Virtual Power Plant (VPP) and the main voltage optimization criteria can be extended to supply ancillary services to the upper level grid, contributing to the stability of the electric power system. The function then improves the spatial reactive power balance as well as the voltage quality in electric distribution systems and also the spatial balance of active power.   The generic application is capable of supporting the following objectives, which can be changed at different times following present scenarios, operator requests, or other application triggers:   § Ensure standard voltages at customer terminals  §       Minimize feeder segment(s) overload  §          Reduce energy losses  §          Conserve energy   §          Minimize cost of energy  §          Reduce load by a given value while respecting given voltage tolerance (either normal, or emergency)  §          Provide reactive power support for distribution bus and keep the power factor within the given limits at the interface to the higher-level grid   §          Improve the spatial balance of primary control of electric power systems, i.e. P(f) behaviour   §          Provide spinning reserve support  §          Provide compatible combinations of above objectives    This application is constrained by the following limits:  §          Loading limits of grid elements  §          Voltage limits at the equivalent customer terminals  §          Voltage limits in selected point of distribution primaries, including the distribution bus of the substation  §          Reactive power or power factor limits at selected busses  §          Capability limits of distributed energy resources  §          Operating reserve limits  §          Limits of controllable devices: On Load Tap Changer limits, Voltage regulator limits, Capacitor control limits, Distributed generation control limits, Power electronics limits  §          Integral constraints on state of charge of storage devices    The application shall be based on dynamically changing power flow derived from measurements. The function monitors the voltage and power flow in critical points of the controlled grid. The status of the grid required by the control algorithm, based on actual measurements and network topology, may be computed by a State Estimator, that reduce the amount of data to be processed and the number of measurements required in order to create an accurate profile.  In order to pursue one or combinations of the previous defined objectives, the Substation Control System calculates in a coordinated manner the optimal states of the controllable devices (On Load Tap Changers, Switched Capacitor banks, Voltage regulators, Distributed Generators, storage units, flexible loads) across the substation area.   For distributed generators having P(f) or Q(U) local control, the droop capabilities can be dynamically defined and/or activated. As example, if the local voltage value oversteps the parameterized voltage boundary, the generator, that in the normal status operation works with Q=0, modulate the reactive power value, maintaining the same active power production, in order to reach the right voltage level. If the generator is not able to make the correct voltage value, it signals this event to the central voltage control system.  Electric storage devices may function as distributed generators as well as flexible loads at different times and can be operated with integral constraints on the same level of charge after a 24h cycle. Flexible loads include Plug-in Electric Vehicles (PEV).   Considering the voltage profile control, for example, in order to keep the voltage along the lines as constant as possible, in addition to other power equipments, DERs injected reactive or active power is controlled, depending on grid characteristics.  Reactive power control works best in distribution area with mostly inductive characteristic of lines (X/R >> 1, typically HV or MV level) and active power control is used in networks with mostly resistive characteristic of lines (X/R << 1, typically MV or LV level).  In a generic case, the optimization process take into account combinations of technical/economical objectives and constraints, including requirements on power exchange at point of common coupling with the higher-level grid.  The optimization algorithm is not detailed in this generic use case and is assumed to take place locally within the substation. Only  the actions derived from the optimization function are considered.   As part of the coordinated optimization within the substation, suitable devices for control actions are selected. Depending on the particular grid control area where the voltage control is applied and on the optimization objectives, some generation/load units can be controlled either directly by Substation Control System or via the Flexibility Operator.  After any change of equipment state, whether due to substation request or due to local automatic action, the substation is notified about the new state or operating point, including the information on available regulation range.   The application includes the controllable power equipments, distributed generators variables and issue corresponding signals to these variables in the closed-loop control sequences  If during optimization or execution of the solution, the topology of the grid changes, the application is interrupted and the solution is re-optimized. If, during execution, some operations are unsuccessful, solution is re-optimized without involving the malfunctioning devices. If some of the controllable devices are unavailable for remote control, solution does not involve these devices but takes into account their reaction to changes in operating conditions. |

* + *Actors: People, Systems, Applications, Databases, the Power System, and Other Stakeholders*

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| ***Actor Name*** | ***Actor Type*** | ***Actor Description*** |
| Aggregator | Role |  |
| Control Center | System |  |
| Renewable Generation Forecaster | System |  |
| Flexible Load | - | Load that can be modulated |
| DER | - |  |
| Substation Control System (SCS) | Generic Role |  |
| Power Equipment | - |  |

* + *Issues: Legal Contracts, Legal Regulations, Constraints and others*

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| ***Issue -*** ***here specific ones*** | ***Impact of Issue on Use Case*** | ***Reference -*** *law, standard, others* |
| Power quality | Voltage level control algorithm | Norm EN 50160 |

* + *Preconditions, Assumptions, Post condition, Events*

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| ***Actor/System/Information/Contract*** | ***Triggering Event*** | ***Pre-conditions*** | ***Assumption*** |
| ***Substation Control System*** | - | - | The Voltage Control algorithm applies to a HV/MV or MV/LV Substation and operates controllable devices installed on the underlying grid |
| ***DER ancillary services*** | - | - | The use of DER ancillary services is defined by contracts or regional regulations. The Substation Control System can operate only DERs having subscribed some agreement. Flexibility operator intermediates between customer owned DER and Substation Control |
| ***Costs of DER ancillary services*** | - | - | Optimization algorithm can take into account dispatching costs for DER active and reactive power. Different remuneration of ancillary services offered by DERs are possible: administrated price: fixed price established by Authority bodies; market price sch |
| ***DER storage*** | - | - | Storage units are owned and operated directly by the Distribution Utility in order to increase grid control capabilities. There is an integral constraints on control strategies to keep a costant level of charge over a 24 hour time horizon. |
| ***Grid measurements*** | - | - | Grid measurements are available from Control center SCADA system and from DERs. |
| ***State Estimation*** | - | - | The State Estimation of the grid in the controlled area underlying the Substation is performed by the Substation Control System. |
| ***Execution of the optimization function*** | - | - | Control loop is executed: Periodically (15â€™) On critical under/overvoltage event On grid topology change Signals related to grid stability (normal, critical, alarm, â€¦) coming from Control center can influence the execution of control voltage algorit |

* + *Referenced Standards and / or Standardization Committees (if available)*

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| ***Relevant Standardization Committees*** | ***Standards supporting the Use Case*** | ***Standard Status*** |
| IEC TC57 | IEC 60870-5-104 | IS - International Standard |
| IEC TC57 | IEC 61850(-7-420) | IS - International Standard |
| IEC TC57 | IEC 62351 | - |
| NIST | NIST SP800-53 &800-82, IR 7628 | - |
| IEC TC57 | IEC 61970 | IS - International Standard |
| IEC TC57 | IEC 61968 | IS - International Standard |

* + *General Remarks*

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| ***General Remarks*** |
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# Drawing or Diagram of Use Case

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| ***Drawing or Diagram of Use Case*** ***- recommended "context diagram" and "sequence diagram" in UML*** |
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# Step by Step Analysis of Use Case

| **S.No** | **Primary Actor** | **Triggering Event** | **Pre-Condition** | **Post-Condition** |
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| PS1 | Substation Control System | - | - | - |

* + ***Steps - -***

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| ***Scenario*** ***Name:*** | | ***PS1*** | | | | |
| ***Step No.*** | ***Event*** | ***Description of Process/Activity*** | ***Information Producer*** | ***Information Receiver*** | ***Information Exchanged*** | ***Technical Require-ments ID***  *see* *Annex A Selection List* |
| 1 | - | 1-Request actual DER measurements and Status | Substation Control System (SCS) | DER | DER measurements &Status |  |
| 2 | - | 2-Request actual grid measurements available in Control Center | Substation Control System (SCS) | - | Grid measurements |  |
| 3 | - | 3-Execute State Estimation and optimized Set point Calculation Algorithm | Substation Control System (SCS) | Substation Control System (SCS) | State Estimation &Set point Calculation |  |
| 4 | - | 4-Send power equipment Set point | Substation Control System (SCS) | Power Equipment | Set power equipment Set point: On Load tap changers (OLTC) Switched Capacitor banks FACTS devices Voltage Regulators |  |
| 5 | - | 5-Send DER Set point | Substation Control System (SCS) | DER | DER Set point |  |
| 6 | - | 6-Send Flexible load Set point. Repeat steps 1-6 periodically or following particular events, as specified in Assumptions (â€œExecution of the optimization functionâ€). | Substation Control System (SCS) | Flexible Load | Flexible load Set point |  |
| 7 | Operator changes algorithm parameters. | 7-Send signals influencing the execution of control voltage algorithm (e.g. changing optimization criteria or overriding commands). | - | Substation Control System (SCS) | P, Q or power factor constraints at common connection point with the higher-level grid. Function Enable/disable. Selection of optimization mode and constraints. |  |
| 8 | Grid topology changes. | 8-Send configuration change of the controlled MV grid (grid topology reconfiguration) | - | Substation Control System (SCS) | Updated Grid Topology. |  |
| 9 | New feature information available. | 9-Update Features information (Nominal power, Capability, Controllability, etc.) of DER installed on the controlled area | - | Substation Control System (SCS) | Updated Flexible Load/DER: features, availability. |  |
| 10 | New load/generation program available. | 10-Update Load/generation program for each customer | - | Substation Control System (SCS) | Updated Load/generation program for each customer |  |
| 11 | New generation forecast available. | 11-Update Generation forecast for each DER | Renewable Generation Forecaster | Substation Control System (SCS) | Updated Gen Forecast for each DER |  |
| 12 | New costs available. | 12-Update Energy / Ancillary Costs | - | Substation Control System (SCS) | Updated Energy / Ancillary Costs |  |