

Investigation In Finding The Role Of Active Loads In The Electrical Grid Dominated By Power Electronics

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ABSTRACT:

Distributed AC power systems with large percentage of constant power loads (CPL) are susceptible to potential voltage stability problems under abnormal operating conditions. The design of the control system of the CPL can greatly influence the power system stability. In this paper, main focus has been put to use CPLs for transient stability enhancement and fault ride through (FRT) under balanced/unbalanced grid voltage dips instead of employing a dedicated compensating device for such ancillary grid services. The influence of introducing reactive current control by active rectifiers on the CPL instability, and the resulting contribution to the overall voltage stability is investigated and evaluated. A large increase in transient stability margins has been observed under balanced grid voltage sags when CPLs provide the ancillary reactive power during the fault and avoid a possible voltage collapse due to excessive reactive power consumption. Centralized reactive compensation by a STATCOM is used as reference to compare with distributed compensation by the CPLs. Results shows that required distributed injection of reactive current is lower compared to the rating of a centralized STATCOM.

Keywords: AC power systems, Power Electronics, Active loads, Constant Power Load

INTRODUCTION:

The capabilities and economy of power electronics system are determined by the active devices that are available. Power electronics is the study of processing and controlling the flow of electric energy by supplying voltages and currents in a form that is suited for user loads. The goals of using power electronics are to obtain the benefit of lower cost, small power loss and high energy efficiency. Generally, smart grid is comprised of number of distributed energy resources (DERs) and power electronic (PE) interfaces, which must be properly exploited to address the power quality issues and increase the distribution system stability and efficiency. On the other hand, distributed generation (DG) feeding a micro grid offers many advantages. Having the DG close to the point of power consumption reduces the transmission and distribution losses and prevents network congestion. Moreover, the chances of having the blackout are also reduced because many of these micro grids may be able to

operate in islanded or standalone mode while being disconnected from the high or medium voltage transmission networks under abnormal grid conditions and contingencies. There are many methods employed to address the stability related issues in a smart electrical network. One of them is the use of a centralized shunt connected static synchronous compensator (STATCOM) in grid-connected micro grids to improve the voltage sags/swells and unbalances

LITERATURE REVIEW:

Daijafan Mao et al (2019) establishes a new context where the power-electronics-based (PE-based) load, represented by Plug-in Electric Vehicles, dominates the total load composition in power systems. The inherent fast dynamics of PE-based load make conventional approaches of voltage stability analysis unsuitable. Under the new context, the mechanism and impacts of voltage instability under large disturbances have been analytically revealed. The Region of Attraction (ROA) of the stable equilibrium point has been estimated through nonlinear dynamical system theories, which implies a critical clearing time post grid disturbance.

Tino Wymann et al (2015) Voltage dips or power interruptions in the grid cause huge problems for the users. The ride-through behaviour of frequency converters can be a very good solution to bridge the gap. This paper reconsiders the topic on a power drive system level and gives practical information to the users, based on the experience of a drive manufacturer.

Bhargava Reddy, B et al (2011) Smart grid is a concept of matching electricity production with demand using multiple identical generators which can start, stop and operate efficiently at chosen load, independently of the others, making them suitable for base load and peaking power generation. This concept presents a new control strategy for voltage source converters (VSCs) in the frequency angle domain which enables dc-link voltage regulation via frequency and load angle adjustment. Two different variants are proposed for dc link voltage control; namely direct dc-link voltage control and indirect dc-link voltage controller. Simulation results provided to validate the controller effectiveness.

CPLs in AC Distribution System: The responsibility of the source subsystem is to maintain the amplitude and frequency of the bus voltage at a fixed level. It has been assumed that some of the loads, which are supplied from source subsystem, are tightly regulated controlled or uncontrolled PE converters. Therefore, these PE loads, which may be voltage regulators or motor drives, behave as CPLs.

Figure shows the CPL and conventional constant voltage load (CVL) connected to a typical bus. It also shows the equivalent circuit of the source subsystem at this typical bus with equivalent impedance [38]. Because P and R are equivalent constant power and constant voltage loads, respectively, they can change according to the number and power of the loads. It means that if a load is disconnected or a new load is added, P and R may change accordingly. However, P and R instantaneously show the equivalent power of CPLs and the equivalent resistance of CVLs, respectively. In order to determine the necessary conditions for stability of the circuit shown in Fig, CPL must be modelled.

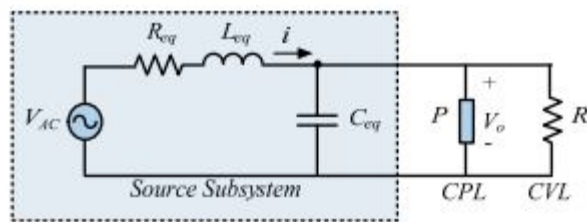


Fig: CPL and CVL connected to a typical bus

Voltage Transient Behaviour and CCT:

To investigate the effect of the CPLs in the transient behaviour of the system voltage, a three-phase to ground fault is simulated to obtain a voltage drop equal to 20% of the nominal voltage. Simulations are carried under this condition to obtain the critical clearing time (CCT); that is the maximum time before the system becomes unstable due to voltage collapse. Fig. 5 a) and b) shows simulation results of two cases of CPL in the system; 80% share of CPLs with and without control of reactive current. This is because of the extra functionality of reactive current control to support the system voltage. This extra functionality can however be at the expense of an increment in the required current rating of the semiconductor devices in the AC/DC converter that regulates the CPLs.

Simulation model of the distributed AC system: In the power system configuration shown in Fig. 2 the asynchronous generator represents a wind turbine feeding power to a line with 3 CPLs. The line is connected to the main grid by the inductance L_g and there is an inductance corresponding to 3 km of transmission line between the different loads. To investigate the transient behavior of the system voltage with CPLs and observe the stability limits, a three-phase line to ground fault is simulated at point A. The model can also consider induction motor load directly connected to the line, accounting for part of the total load.

The reactive current control introduced is based on standard control techniques that are known from implementation in dedicated converter systems for reactive power control such as the STATCOM and for reactive power by the power electronic converters of wind turbines and other distributed generators.

Microgrid Structure with High Share of CPLs

The investigated microgrid is shown in Figure 4.13. It consists of a 3 MW fixed speed SCIG based wind farm connected directly to the medium voltage grid. Several CPLs are connected to the low voltage distribution bus. It has been assumed that the distribution level is entirely dominated by the consumers with PE interfaces at the front end. An aggregate model of the wind farm is used so that the sum of the turbines is modeled as one generator using the standard T-equivalent circuit

RESULTS:

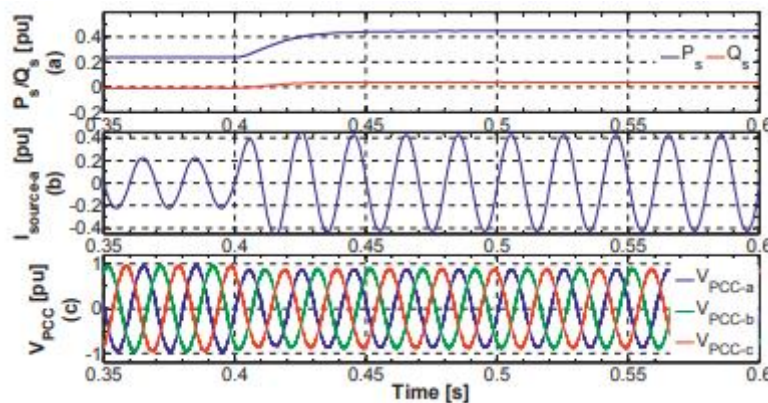


Figure: (a) Phase-a source current and PCC voltage for total simulation time (b) Source current (c) PCC voltage THD

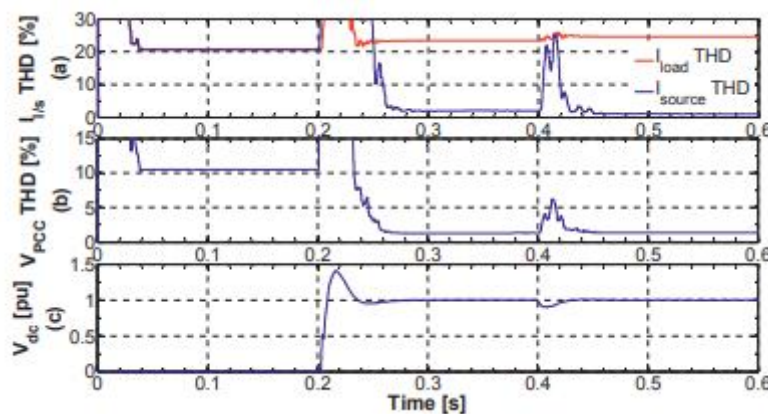


Figure: (a) Source and load current THD (b) PCC voltage THD (c) DC link voltage

At time $t=0.4s$, when CPL starts consuming active power from the source the THD of the source current is further reduced to 1.1%. The reason for this is the addition of perfect sinusoidal current drawn by the CPL to the total source current that has very small distortion due to CPL switching operation. Figure 5.9c shows that the DC-link voltage controller provides a very stiff control during the whole simulation period irrespective of CPL mode of operation. The voltage remains fixed to the specified value. Shunt active filtering as an ancillary service is an added feature of the CPL if its control is modified in accordance with the application requirements.

The controller parameters found from the tuning methods are incorporated in the control system of the CPL. A simulation study is done to verify the results from the analytical study. The presence of induction generator makes it impossible to distinguish between the instability caused by the converter control and the transient instability following a major grid side disturbance. The grid voltage is 1.0 pu and the corresponding value of the DC link voltage is also maintained to 1.0 pu. There is a small overshoot and initial transients in the DC link voltage before settling down to the given reference value. The performance of the system is very stable and the outer voltage controller is following the reference value.

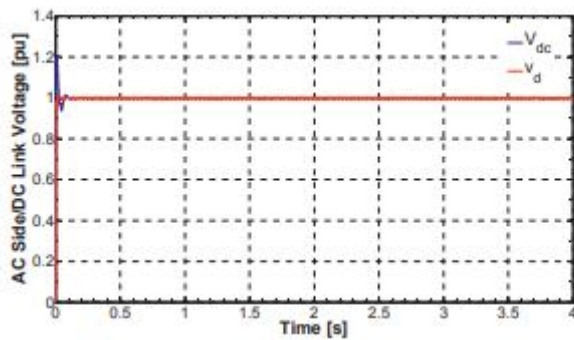


Fig: AC/DC side voltages for steady state operation

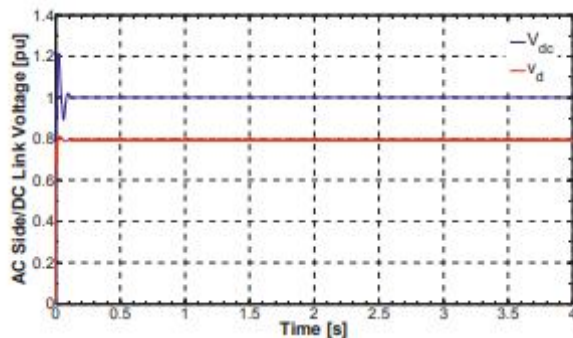


Fig: AC/DC side voltages for 20% grid voltage sag

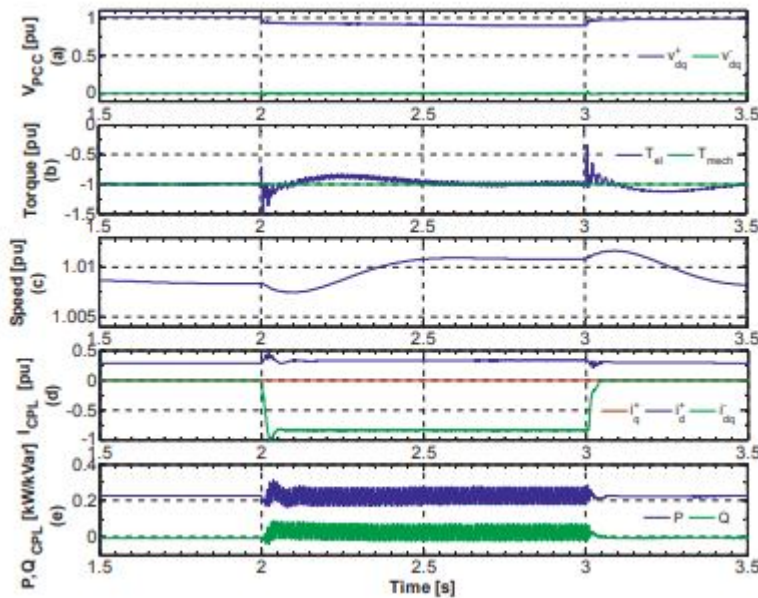


Fig: Simulation results with CPL negative sequence voltage control (a) Positive and negative sequence voltages at PCC (b) SCIG Torque (c) SCIG speed (d) Positive and negative component of compensating current (e) CPL active and reactive powers

During the fault, both the active and reactive powers exhibit second order harmonic as a result of interaction between the opposite sequence voltage and current components. The

input active power oscillates around a constant load demand. From the load side perspective, these oscillations are undesirable.

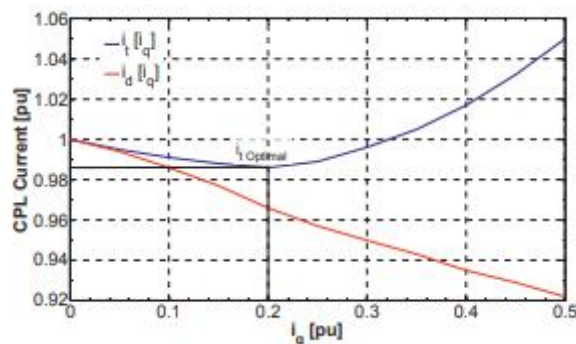


Fig: Optimal total current for a CPL consuming 750 kW

Figure shows the simulation results for the two cases with double grid impedance while CPL is consuming 500 kW. In this case, the operating point has moved further to the right and the injected reactive current is now 0.2 pu for steady state to get the optimal total current.

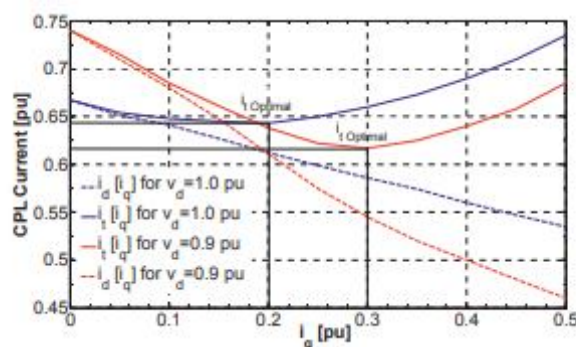


Fig: Optimal total current for a CPL consuming 500 kW with modified grid parameters

Optimization of total current for a CPL will play an important role with regards to the future development of loss minimization algorithms for residential and industrial microgrids.

CONCLUSION:

Effects of negative incremental resistance of CPLs in distributed AC systems is presented and discussed. The phenomena is explained and verified by simulation on a simplified power system model with high share of CPLs. The paper investigates the benefits of introducing the extra functionality of reactive current control in the CPLs control strategy to allow for the injection of reactive current in the event of voltage dips to support voltage stability. It is important to note that if future loads will support the system voltage by injecting reactive power, a different approach is needed in the design stage of CPL drive system in addition to the individual optimization typically done by manufacturers to fulfil standards such as grid codes, THD and EMC requirements. These are not necessarily sufficient to achieve what would be optimal from the point of view of the system performance and operation, especially during abnormal operating conditions such as voltage dips.

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