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Integrating Energy Storage for Multiterminal DC (MTDC) Bus

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ABSTRACT:*As a way to make sure the stable operation of multiplerectifiers and inverters from the equal DC bus, thevoltage/cutting-edge order commands for all power converters inboth systems are commonly coordinated through the use ofhigh speed communications with a centralized coordinationcontroller. This paper proposes an stepped forward number one control layer for an MTDC gadget. The idea is primarily based at the mixture of a slump control technique and dc bus signaling so as toprovide a extra regular and flexible solution. In this paper, differentdroop characteristics are proposed for the diverse factors linked to the dc bus. They all are particularly tailored around fiveoperation bands, which depend on the dc bus voltage stage.*

KEYWORDS-Distributed generation, droop control, energystorage, MTDC systems, parallel connection of converters

I. INTRODUCTION

MTDC energy structures expand the traditional highvoltage DC (HVDC) concept of a single rectifierinverter pair to encompass two or greater rectifierssupplying more than one load converters. The complexityof acting rapid, coordinated manage of all systemconverters inside the face of electrical disturbances limitsthe number of terminals that can be involved. Fastcommunications of control signals between theconverters is likewise required. As an opportunity tocentralized manipulate, allotted voltage "hunch"control has been proven to provide rapid, coordinatedcontrol of all machine converters with out inter-terminalcommunications [1]. However, this approach islimited to strength structures which are tightly coupledelectrically, along with business power systemapplications [3][4] and structures employing hightemperature superconducting (HTS) distributioncables [5].

The U.S. Navy's proposed use of medium voltagedc energy distribution in its Next Generation(shipboard) Integrated Power System (NGIPS) is aclosely-coupled strength system [6]. Its multi-zonaldesign is much like a terrestrial, MTDC topology.Four or extra fuel turbine generator units deliver powervia rectifier modules to a DC ring bus that runs alongthe port and starboard sides of the ship. These five-10kvdc longitudinal buses deliver MVDC energy toport and starboard DC-DC converters in every of fiveload center zones from bow to stern. System stabilitybecomes an crucial problem as converters across theship are energized/de-energized because of equipmentmalfunction, system faults, or reconfiguration actionsfollowing warfare damage. Sudden electricaldisturbances from the operation of high power pulsedloads, strength regeneration from strength storage devicesand AC/DC faults in addition stress converter stability.The reliability of a ship-extensive, converter controlarchitecture employing a centralized energypowermanagement machine is also a challenge while battledamage eventualities are considered.

Because of those stability and reliabilitychallenges, the NGIPS MVDC device may want to benefitfrom the application of a MTDC disbursed convertercontrol scheme, along with voltage stoop. Under normaloperating conditions a centralized Power managementsystem optimizes the voltage/contemporary orders of allsystem rectifiers and inverters in accordance withmission necessities. This coordination is necessaryto make certain that supply and load converters on the samedc bus function stably collectively and proportion the loadappropriately. Should the PMS lose the capability tocommunicate with a generator's rectifier due toequipment malfunction or conflict harm, bus stabilityand rectifier modern sharing of the overall bus loadingcan be reliably supplied for thru a fallbackconverter manipulate scheme that employs voltage slump.

This is the fundamental premise of this paper.The use of voltage hunch in commercial mtdcsystems is defined first with its software toshipboard DC power systems. In order to demonstratethe overall performance opportunities in a shipboard machine,simulation results for slump control in a notional fivezone ship MVDC energy machine are supplied. Thesesimulations had been executed the usage of a notional destroyermvdc included power system version evolved the 14-rack, Real-time Digital Simulator [1] at floridastate University's Center for Advanced powersystems (FSU/CAPS).

II. MTDC DISTRIBUTED VOLTAGE DROOP CONTROL

The idea of voltage slump manage in mtdcsystems is derived from the well-known use offrequency stoop in AC electricity generation. Frequencyor pace-strength droop gives a way for 2 or moregenerators to operate stably on the same bus. Busfrequency will become a not unusual communications signalsince the velocity governing controllers of the paralleledgenerators' prime movers use pace/frequency as thecontrol variable.

In the identical way, for MTDC structures where voltagedrops alongside the bus are small, bus voltage may be usedas a commonplace communications signal betweenparalleled converters providing or fed by using the bus. Busvoltage is the manage variable for voltage controllersin the paralleled converters. A voltage droop functionenables the converters to perform stably with eachother and for rectifiers to proportionately proportion theoverall bus load.

The requirement for small voltage drops alongside thedc bus is a crucial one for MTDC structures on account that thevoltage dimension at all converters ought to besubstantially the identical for the technique to be accurate.This is why voltage slump is maximum applicable toterrestrial power systems that hire superconductingcables and industrial or shipboard strength systems inwhich cable lengths are small. However, Lasseterindicated that for structures with lossy cables, everyconverter could must infer the fee of somevoltage to adjust based totally on its local dc voltage andcurrent records and a information of the networkcomponents in carrier [2].

One advantage of voltage hunch in paralleling rectifiersis the capability to present day share the overall bus loadautomatically many of the rectifiers with out the needfor communicating modern orders between theconverters. Fig.1 shows the sloping droopcharacteristics for 3 rectifiers in parallel. Thesystem is started with each rectifier offering equalcurrents at operating point A. The overall bus load isthen reduced, causing the machine to move tooperating point B. The 1/3 rectifier then shuts down,and its loading is picked up by the alternative two rectifiers,transferring the device to running point C. The rectifiersshare the overall load modern-day equally due to the fact theircurves have the same slope. Also, the DC bus voltagelevel may be with ease regulated by choosing the advantage ofthe active stoop slope.

A 2nd benefit of voltage hunch is its capacity toregulate bus voltage by running all the rectifiersin joint voltage control mode. In this mode, changingthe slump slope adjustments the output modern. This ismore applicable than the traditional MTDC terminalcoordination scheme wherein one terminal in a multiterminal gadget sets the voltage for the common buswhile all different terminals function in cutting-edge or powercontrol mode. If the voltage placing terminal (VST)is going offline, or hits a current restriction, mode switchingmust occur in which one of the other converters (be itrectifier or inverter) is directed to take over the function ofsetting bus voltage. This mode switching is complexand limits the range of terminals that can beaccommodated in a MTDC gadget.

Voltage stoop allows numerous rectifiers connectedin parallel to operate stably in a joint voltage controlmode without the want for outside coordination. Theloss of one or extra rectifiers might have noappreciable affect on bus regulation. It can also affecta rapid recuperation in bus voltage following systemdisturbances. Without hunch, paralleled voltagecontrollers might "combat" to benefit manipulate of thecommon bus voltage. The controllers' currentinjections into the bus could then swing back andforth between them in an uncontrolled fashion. Thenegative slope characteristic of the hunch functiondampens these oscillations out and causes thecontrollers to transport "in step".

Voltage droop is carried out in MTDC systemsthrough the addition of a stoop thing to the voltagecontroller that acts like an imaginary series resistancein the converter's output current course. Linecommutated rectifier bridges have a natural droopcharacteristic through a modern-established voltagedrop from commutation overlap [2]. It is typicallymodeled as a commutating resistance (Rc). However,this natural stoop is small in significance and itsshallow I-V characteristic slope does no longer offer muchcontrol over output voltage. Instead, a much largercontrollable slump factor (Kα) is delivered to the rectifiervoltage controls.

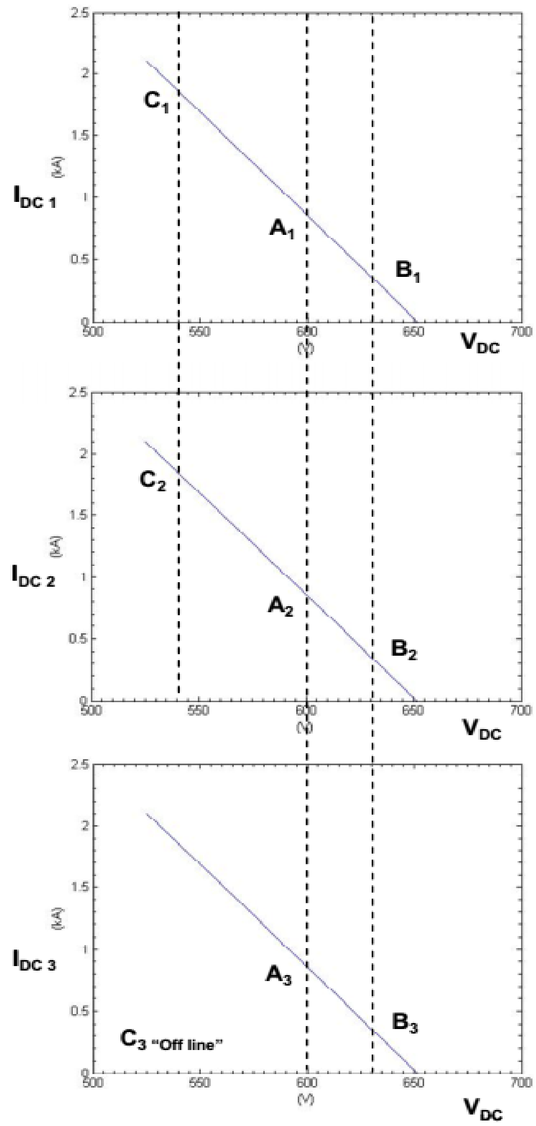

Fig.1 Voltage Droop Characteristics

When the droop slope for each rectifier onthe bus is the same, the rectifiers equally share thetotal load current. Changing the slope forselected rectifiers allows them to share theoverall bus load with different proportions.

III. SYSTEM DESCRIPTION

A conceptual system appropriate for the control of a PV powerplant with a couple of ES units is sketched in Fig. 1. Here, severalpower converters are related to a commonplace dc bus, forminga fundamental

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multiterminal dc network with multiple connections tothe ac grid. For illustration purposes, two special connectiontypes with the ac gadget are proven. As it is going to be seen in the following sections, one is essential (converter four) and is suitable forconnections to vulnerable grids, even as the alternative (converter 2) allowsfor a greater bendy connection. A hierarchical manage structurewould be the first-rate preference for manipulate and safe operation of such asystem. In this sort of control strategy, the lowest manage level,specifically, the primary manage, is carried out locally in each converter and has to perform independently with out making use ofexternal verbal exchange channels. The dc bus voltage level canbe used as a international decision parameter, and manipulate movements canbe domestically taken based totally on this value. The secondary manipulate layeris implemented as a centralized controller and primarily based on measurements from all the connected devices, should act like an
Electricity-control system and operation optimizer through settingthe appropriate references to the number one manage.

For this, 5 running bands are definedfor the network voltage. The normal operation (NO) band is thevoltage c programming language for which the gadget is taken into consideration to be understandard operation, and the balance between load and manufacturing is happy. The NO band is surrounded by using two protection bands;one inside the decrease component (SL) and one within the higher (SH). These
Bands are taken into consideration for the instances of transients or other suddenevents that deflect the dc bus voltage from the NO location. Finally, a important excessive (CH) band and a essential low (CL) bandare considered. When the voltage reaches those bands, there isa mismatch between production and consumption which could nolonger be supported by way of the storage factors.

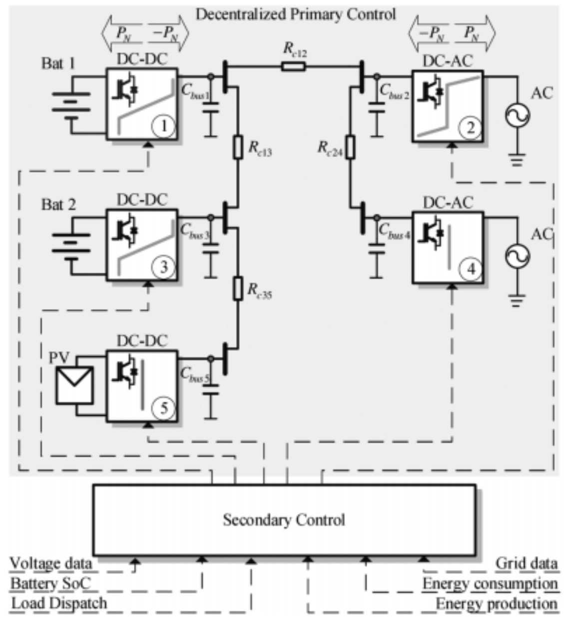

Fig. 2.Conceptual view of the control and management of the common dc bussystem.

Before analyzing each of the droop characteristics, a convention for the sign of the currents has to be set. Throughout thispaper, a positive current on the dc bus side is considered to be aload current that is being drained from the dc bus. On the otherhand, negative current is considered to be injected into the dcgrid as seen on the top of Fig. 2.

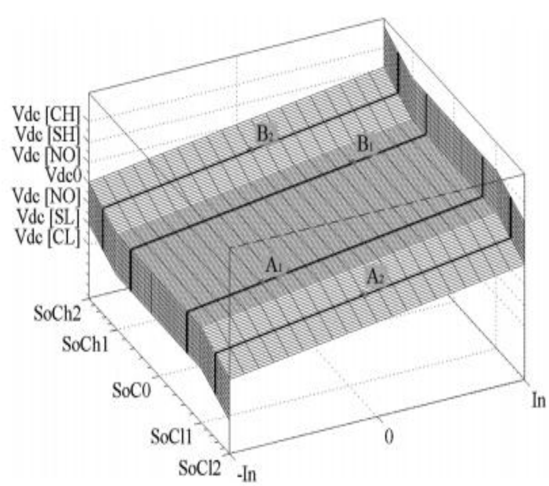

Fig. 3. Droop surface for energy-storage elements.

The droop surface presented in Fig. 2 is proposed for the control of the converter connected to batteries.

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The definition of thisdroop characteristic starts by fixing its slope and the nominalcurrent.

IV. TUNING CONTROL SYSTEM

The block diagram depicted in Fig. 4 presents the proposedelectrical configuration and control structure for the dc side ofa single element of the system presented in Fig. 2. As can beseen, the proposed structure is comprised of two loops: 1) an internal current control loop, based on a PI controller, and 2) anouter voltage loop, controlled through one of the droop curvespreviously presented.

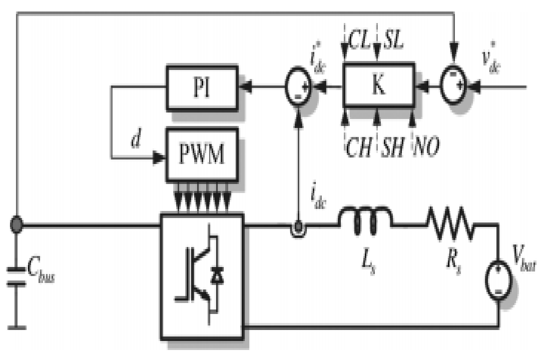

Fig. 4. Control block diagram for one element connected to the common dcbus system

In order to analyze the scaling and design of the system, aboost dc-dc converter connected to a battery was chosen asa study case. The starting point of the analysis is the definition of the main parameters to be used in the control of theconverte

A. Tunning of the Controller

It can be shown that the current control loop of the convertercan be properly shaped so that it can be approximated with alow-pass filter in closed-loop form. For example, this can beachieved if the design criteria for a PI controller proposed is followed. This methodology designs the gains of thecontroller based on the value of the passive elements of theconverter and on the imposed values of bandwidth and phasemargin.

V. CONCLUSION

This paper best addressed one small, butimportant, problem associated with implementation of amvdc.as an instance, the protectionsystem's detection and isolation of DC faults is asignificant venture no longer considered in this paper.The proposed manage method can pay unique interest to theintegration of strength storage into MTDC structures and it consists of the operating situations of the ES factors in the designof the manipulate.hence, a brand new slump surface is received by way of takinginto account the soc of the garage and the dc bus voltage stage.this selection allows the primary control layer to higher cope with theenergy stored within the dc community, and it adapts the manage profile so as to save you overcharges and deep discharges in thestorage factors

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