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Hybrid Power System for VSC HVDC Using Matlab

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Abstract: *Presently strength system operates beneath a excessive pressure degree which modified into not noted at the instant they were designed. The operating situations of strength system are being threatened shape the reliability, controllability and security factor of view. HVDC transmission brings a way to have at ease and improve the steadiness margins of strength machine. The feature like independent control of real and reactive electricity improves the strength device stability and guarantees an inexperienced power switch. This Project gives the manipulate strategy used for VSC-HVDC transmission to improve the quick and voltage stability of strength gadget. Transientinstability due to a device faults overcome because of the fast energy run again capability of the VSC-HVDC transmission. VSC-HVDC prevents the tool from quick instability via its instant electricity reversal capability. The voltage help functionality of VSC gadget helps to shield the gadget from voltage fall apart, finally losing of synchronism may be avoided. A grid related lower lower back to again VSC-HVDC modeled in MATLAB/ Simulink environment and a current mode control approach have become finished. The simulation turned into completed to have an statement of a quicker and impartial manipulate of real and reactive strength.*
Keywords: *VSC-HVDC, stability, pulse width modulation (PWM)*

I. Introduction

THE GROWING complexity of EPS (electric power sys-tem) poses new challenges to ensure its reliability andstability. At the same time, the progress achieved in powerelectronics has demonstrated the HVDC (High-voltage directcurrent) technologies effectiveness in solution of conventionaltasks such as asynchronous interconnection, long distancetransmission, increasing the local and systemic controllabil-ity of EPS, as well as the relatively new challenges relatedwith integration of the distributed renewable energy sourcesinto HVAC (High-voltage alternating current) system [1]–[3].Converter based on power semiconductors is the main ele-ment of these technologies. Currently, the scheme of HVDCbased on two types of converters - line commutated con-verter (LCC) and voltage-source converter (VSC) - is usedin EPS. It should be noted that VSC based on fully con-trolled high-speed power switches (IGBT, GTO) has several advantages compared to LCC [2], [4], [5], such as:

- the independent control of active and reactivepower;
- the provision of reverse of power flow without changing the polarity of thevoltage.

At the same time, the possibility of parallel-series connec- tions and a high speed commutation of power semiconductors (switching time of the IGBT (Insulated-gate bipolar transistor) is 5 μs) allow the formation of a more sinusoidal wave of volt- age,whichconsequentlyreducestheTotalharmonicdistortion, and as a result, the optimization of parameters of the HVDC filter on the AC (alternating current)side.
Theflexibilityandhighspeedcontrollabilityof VSCHVDC enable to use them as additional voltage regulation and damp- ing of low frequency oscillations in the EPS, caused by a short circuit, disconnection of generators and etc.[1],[6].
Nevertheless,thepracticalnecessityofrelevantresearchand analysis to ensure safe and reliable operation of these tech- nologies and EPS in general are emphasized by many research groups and engineers[7]–[9].
The most complex and urgent tasks include [10], [11]:

- the analysis of the mutual influence of HVDC and HVAC systems, including their control and protection upon each other and the EPS as the whole, especially in transient conditions;
- the development, testing and adjustment of the local and systemic automatic control and protection systems.

A solution of these tasks requires full-scale experiments in real EPS, which cannot be conducted. Therefore, the control and monitoring system (like a Wide Area Control System) and hard- and software simulation tools are the main sources used to obtain the information required for analysis of the EPS operation

[8]. Study of experience of their application in practice allows us to define advantages and disadvantages of these approaches and identify promising directions of the development of methods and tools of EPS analysis. Oneof the most striking examples of the application of the control and monitoring system for the EPS analysis containing HVDC technologies can be viewed in the EPS of South China [8]. According to [8], the received for several years emergency shutdown data of HVDC, that led to cascading failures and separation of EPS, ensured the development of effective con- figuration of automatic control system (ACS) of hybrid HVAC and HVDC systems and the prevention of similar accidents in thefuture.

There are some weaknesses in this approach:

- the high complexity associated with the analysis of disturbance processes in case of low observability of the EPS;
- the limited applicability of the measurement results to set up the ACS of hybrid HVAC and HVDCsystems;
- the occurrence of previously un observed disturbances;
- the existence of a wide range of all possible pre- emergency modes ofEPS;
- the significant time resources required for the various experiment sin areal EP Sand further analysis of obtained results.

That is why the control and monitoring system can not be regarded as a primary source of information for the analysis of the mutual influence of HVDC and HVAC systems. However, it can be used to verify the results of EPS simulation [8], [9]. At the same time, the reliability and adequacy of the simu- lation results will depend on the chosen simulation methods and tools.

The rest of this paper is organized as follows. Section II introduces the HVDC simulation challenges and proposes alternative tools based on hybrid real time simulation concept. Section III presents the VSC HVDC simulation including adequate representation of commutation process of real IGBT and experimental research of the 2-level VSC HVDC model in EPS. Conclusions are stated in Section IV.

I. THE SIMULATION CHALLENGES

To solve the problem of the reliability and adequacy of the simulation processes in a real VSC HVDC the modeling sys- tem should take into account the specifics of the operation of these devices, in particular:

- the phase-phase operation ofVSC;
- the use of high-speed fully controlled power semiconductors;
- the continuous high-speed operation in all possible nor- mal,emergency and post-emergency operating conditions ofEPS.

Furthermore, to solve the above mentioned prob- lems, the simulation systems should meet the following requirements [10], [12],[13]:

- the models of EPS elements must be three-phase (or more) to account properly for all the unbalanced conditions;
- the simulator must be capable (scalable) to implement an EPS model of anysize;
- the simulation of EPS must exclude the decomposition of processes and limitations on their duration (without separationofelectro magnetic and electromechanicaltran- sient processes modeling in power equipment and EPS as awhole);
- the real-time simulation and the possibility of intercon- nection with external devices and systems.

Currently, digital modeling complexes are widely used for analysis of the EPS (RTDS, HYPERSIM [9], [14] and others). These complexes have shown to be successful in the simula- tion of electromagnetic transients and closed loop testing of ACS, but the numerical integration methods used in digital simulation tools do not enable to perform real time simu- lations of EPS without processes of decomposition over an unlimited period of time because of the integration time step issue.

Additionally, the digital simulation of large EPS is affected by problems associated with the limitations on the size of a model solved by a single processor. Thus, the model par- titioning and application of the travelling wave transmission line models to connect the parts of a power system model distributed between several processors is required. A trick of the application of the travelling wave model is that a traveling time of a transmission line has to be greater or equal to an integration time step which is not always accessible and thus may require forced correction of inductance and capacitance values of a transmission line model.

The distribution of EPS model limits the number of pro- cessors, that can be connected to one node, and leads to forced simplifications and equivalent representations of power equipment and EPS models. These limitations of digital mod- eling complexes are shown in simulation of short transmission line (in back-to-back HVDC system), or simulation of Multi- terminal HVDC projects with a short DC (direct current) link[15].

At the same time the issue of simulating in real time large EPS without separationofelectromagnetic and electro-mechanical transient processes is not solved in full [16], [17]. This statement is confirmed by observed trends in research and development of hybrid simulation tools, based on application of different numerical simulation methods [7],[15]–[17].

However, after the detailed analysis of some of mentioned in [16] and [17] hybrid complexes obviously that required detailed and comprehensive modeling of EPS is not fully achieved. Thus, in [17] to analyze the processes caused by faults in HVDC convertors authors used simulation time step around 50 μs, whereas the switching time of Gate turn- off thyristor is about 30 μs, for IGBT 5 μs. Besides the data exchange between the used complexes is carried out with bigger simulation time step than the simulation time step of electromagnetic transientsmodeling.

To solve mentioned issue of real time simulation of HVDC systems and EPS as a whole, the hybrid simulation technology based on the application of analog, digital and physical model- ing approaches and realized in Hybrid Real-time Simulator of EPS (HRTSim), developed in Tomsk Polytechnic University, isproposed.

The results of the development and research of the VSC model, realized in HRTSim, are shown in this article.

A. TheConceptsofHybridSimulationofEPS

The concept of hybrid simulation is based on the use of three modeling approaches: analog, digital and physical, each of which achieves maximum efficiency in solving individual subtasks. A detailed description of the concepts and tools is presented in [18] and [19].

The basic points of the concepts are:

- the power equipment of EPS is described via complete systems of differential equations adequately representing the whole significant range of quasi-steady and transient processes in this equipment and forming comprehen- sivemathematical models of corresponding types of the simulated equipment;
- the method ologicallyaccurate with guaranteed instrumen- talerr or solution of differential equation system sin real

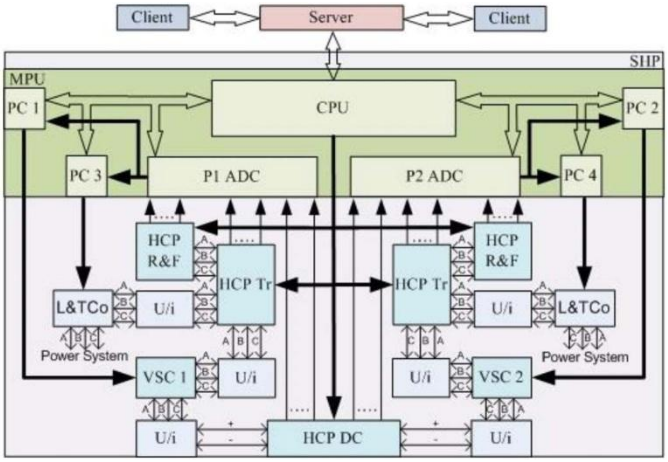

Fig.1. The structural diagram of the SHP of the VSC HVDCmodel: MPU - microprocessor unit; CPU - central processing unit; P1 ADC and P2 ADC - processors of analog-to-digital converters;

time and over an unlimited period of time are carried out by means of the continuous implicit integration method;

- all types of commutation of power equipment, including the power semiconductors, are carried out on a model physicallevel;
- the interconnection between a physical model and mathematical simulation levels is provided by means of appropriate voltage-currentconverters;
- a mutual conversion of mathematical and model physical variables in conjunction with simulation on the physical model level of the commutation of power equipment provides the ability of unlimited scalability of the simulatedEPS;
- all informational and control functions, as well as modeling control and protection systems are implemented on a digital level using a digital-to-analog, analog-to-digital conversion and specializedlocal and server software.

The given concept is realized in the specialized soft- ware and hardware hybrid complex - Hybrid Real-Time Simulator (HRTSim) of EPS.

Specialized hybrid processor (SHP) is the basic element of the modularstructure of the HRT Simand

providesanadequate comprehensivesimulation in he real-time of power equipment models,aswellascontrolandprotection systems.
In Figure 1 and 2 the structure and appearance of the developed experimental SHP of the 2-level VSC HVDC model areshown.

According to the above concept, the solution of compre- hensive mathematical models of the simulated equipment is carried out via the hybrid coprocessors(HCP).The result of solution is transmitted to the MPU (microprocessor unit) via the PADC (processors of analog-to-digital converter). The wholerangeofdatatransformationsrequiredtooversee the process of simulation, as well as real-time control of parameters of the modeled power equipment, depending on the desired solution speed of a control algorithm, are implemented in the MPU.

The universality of the concept and modular structure of the HTRSim allow the development of a model of any element of EPS, including devices and HVDC, and to integrate them into the HTRSim, as well as to provide interconnection with various external software and hardware tools: operational information systems, SCADA system etc.[20].

II. VSC Simulation

To createanadequatemodelofHVDCitisnecessarytopro- vide completeness and accuracy of the process description in the steady-state and transient operating conditions, determined bymodelingimplementationerrorsatallthementioned digital, analog, and physical levels of simulation. Digital simulation iscarriedoutonlyforthecontrolsystemofHVDC.

Modeling errors at the physical model level lead to a devia-tion of loss level, distortion of voltage and current waveforms on both the DC and AC side in the significant frequency spectrum of the EPS. Based on this, the simulation of process at the physical model level is critical to the modeling results, especially for the pulse mode of VSC. Errors at this level can be caused by incorrect characteristics of power semiconductors or parameters of the DC circuit. The latter problemissuccessfullysolvedbytheselectionofcomponents. The characteristics of the physical models of power semicon- ductors require additional analysis and will be addressed in futureworks.

A. Simulation of CommutationProcess

Asmentionedabove,thephysicalmodellevelisparticularly important, because at this level an operation of power switches is modeled via integrated microelectronic digitally controlled analog switches(DCAS).

Consequently, the equivalent circuit of DCAS can be adapted to simulate real power switches. Analysis of equiv-alentcircuits of DCAS and real IGBT (type 5SNR), a comparison of their parameters, taking into account modal and technical scaling coefficients were carried out to verify the adequacy of thissimulation.

It should be noted that the character of the transition process can be adapted by appropriate selection of parameters

III. Conclusion

The specialized concept of a hybrid simulation and the results of its experimental realization show the possibility and efficiency of the proposed approach to the development of the models of power semiconductors and VSC implemented onthem.

The obtained results allow us to carry out a detailed rep- resentation of commutation process of IGBT and adequate modeling of spectral analysis of VSC, as well as comprehen-sive real-time simulation of all the processes in HVDC and EPS as a whole without any decomposition and limitation on their duration.

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