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OPTIMISED DAMPING CONTROL OF ISLANDED DC POWER SYSTEMS USING STATE FEEDBACK

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Abstract **- DC microgrid contains a large number of tightly regulated closed-loop converters, which performance for the constant power loads and may cause stability problem of bus voltage when used as a load since they trend to draw constant power. In order to improve the stability of DC microgrid, this paper proposes a method for stabilization the DC microgrid based on the state feedback. e. In this study, the small disturbance linearised state equation of a DC-power grid with constant power load is derived to estimate the damping characteristics of DC voltage. To enhance the transient voltage stability, a novel DC-voltage damping control method is proposed, where both DC voltage and DC current are used as state feedback variables.**

Index Terms – DC microgrid; stabilization; islanded mode; constant-power load; PID controller

I. Introduction

In recent years, in order to solve problems of the energy shortage, the environmental pollution and other issues, the distributed power, the microgrid has gained more and more attention and application. According to the different types of bus voltage, microgrid can be divided into DC microgrid and AC microgrid. Compared with the AC microgrid, DC microgrid has the advantages of simple control, high efficiency and high reliability, so it is gradually being increasingly concerned about. However, the DC microgrid contains a large number of load converters, whose characteristics are constant power loads and may cause instability of the DC micro grid bus voltage.

Recently, it has become feasible to connect power generation with DC loads using DC-power grids, thanks to simpler converter links and independent power controls. In addition, both frequency regulation and reactive power compensation are no longer included in power system stability regulation. However, with the rapid growth of wind-power generators, photovoltaic (PV) arrays, and DC loads, increased amounts of fluctuating power disturb the balance between power generation and consumption. In addition, the constant power control of voltage source converters (VSCs) for load demand introduces negative impedances to the power grid. These impedances might cause severe DC-voltage fluctuation and instability. The circuit resonance in DC-power grids is considered as the main reason for voltage oscillation. Passive and active damping controllers are designed to improve the system damping. In the passive damping control method, the hardware devices are added to DC lines. Series resistor and parallel resistor-capacitor in filter capacitor branch or parallel resistor-inductor in filter inductor branch is applied to the DC power grid, the results indicate that the system stability can be improved by changing the circuit parameters [1].

Typical DC microgrid structures are shown in Figure 1, which contains a large number of power electronic converters. One of the AC/DC or DC/DC source converters connects with DC microgrid and maintains the bus voltage. When the load point converters work in the constant voltage mode and the control performance is good, the load point converters performance the constant power loads (CPLs) to the DC microgrid. And in ordinary climatic conditions, in order to make full use of renewable energy, the PV, wind power and other distributed power generally work at the maximum power tracking (MPPT) mode. At this time they can be regarded as constant power source.

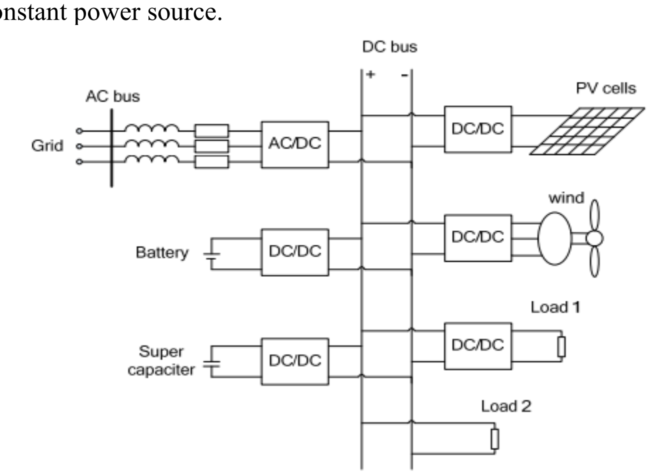

Figure 1 Schematic diagram of a DC microgrid

In the islanded operating state, the battery uses a DC voltage droop control system. The converters used in WTs and PV arrays are regulated to track the maximum power points for improving energy utilisation. The AC load converter operates in a constant power control mode. In addition, the DC loads directly connected to DC buses can be regarded as resistive loads. The purpose of this study is to develop a new approach to improve the voltage damping ability of DC power grids. Thus, a novel state feedback control structure for a B-DC is designed for enhancing voltage damping.

II. Literature Survey

In [1], to enhance the transient voltage stability, a novel DC-voltage damping control method is proposed, where both DC voltage and DC current are used as state feedback variables. Furthermore, two state-feedback control loops are designed to regulate the duty cycle of buck–boost converter added to the energy-storage device. Using the root-locus method, the principle of system pole placement is further discussed to determine the optimal control parameters in the proposed feedback loops, so that the damping characteristics of power system can be optimised. Finally, experimental tests are conducted on a hardware-in-the-loop platform of a typical islanded DC-power system to validate the new control structure. The results demonstrate that the DC-voltage oscillation can be reduced rapidly, which greatly improves the transient stability of DC-power system.

In [2], a VDCM based islanding detection method for DGs using voltage feedback is proposed. The feedback gain that causes system instability in islanding condition while still preserves stability in grid-connected mode is theoretically obtained. To improve the system stability and extend the feedback gain range to realize a better islanding detection performance, an active damping control for stability enhancement is further proposed. The impact of system parameters on stability is analyzed in detail. Both the proposed islanding detection method and stability enhancement for DGs are verified by system simulation.

In [3], a nonlinear tracking controller for multisource EI-DGs operating in islanded microgrids (MGs) is presented. The proposed controller is designed based on interconnection and damping assignment passivity-based controller (IDA-PBC) in the synchronous reference frame (SRF). The controller accounts for the complete dynamics of power conversion units (PCU) components that include DC/DC boost converters coupled with DC/AC inverter units through the interlinking capacitor and are connected to the grid through LC filters. The proposed controller enables PCUs to smoothly suppress the voltage/current and active/reactive power transitions during system operating point changes while precisely track the reference commands generated by the droop controllers. A set of time-domain simulations using realistic modeling of components of PCUs are carried out on a multi-resource islanded MG to validate the results. The performance of the proposed method is compared with that of PI controllers and existing nonlinear control strategies.

In [4], a decentralized coordination control method is proposed for load sharing in paralleled inverters with PV/ battery-VSG units. The whole system can operate in five states according to the relationship between the load, the total PV maximum output power, the total battery charging, discharging power limits. The operation of PV/BES-VSG unit has four modes. In different modes, the subsystems (PV Controller, Battery Controller, VSG Controller) have different control objectives. With the proposed method, the droop characteristics of VSGs can be adaptively adjusted according to the DC bus voltage and frequency of the microgrid because local controllers for each PV/Battery-VSG unit are able to switch operating modes automatically. The simulation results for an islanding microgrid with two PV/BES-VSG units verify that the batteries supply power only when all PV units reach their limits to prolong the battery life, otherwise, the batteries keep charging, therefore the proposed method can maximize the use of PV and ensure the reasonable power sharing between inverters while improving the frequency stability of the microgrid. The proposed method is also applicable to multiple PV/BES-VSG units more than two.

In [5], a comprehensive review on voltage stability of microgrids (MGs) as integral components of a modern power grid is proposed. It reviewed the literature on the impact of microgrid topologies on the voltage stability of microgrids and of the power system to which the MGs are connected. The review includes voltage stability of autonomous AC and DC MGs, and grid-connected AC and DC MGs. Other subjects reviewed in this article are the impact of interlinking converters, DC-link voltage, islanded microgrids, size and duration of disturbances, coordination of voltage control loops, and load dynamics on voltage stability. Methods of static and dynamic analysis for determining voltage stability of microgrids are presented. Voltage stability indices for microgrids are reviewed.

In [6], The PV machine at the side of controller reduces reactive and enhancing THD of the system also wind machine along with DC-DC- converter achieves nearly steady voltage. The Li-ion battery used instead of the lead-acid battery to keep away from frequent upkeep. This proposed hybrid gadget is a absolutely automated underneath supervision of IoT has driven controller and it can screen all parameters such as battery fitness, lamp kingdom, resources outputs from this preventive preservation and see upkeep feasible with decreased manpower. It has the problem as small scale implementation but with the increased ability, it could be linked with grid or utilized for broader packages.

In [7], the advanced manipulate technique for electric reactive power compensation with the assist of electronics components is binary current manage method. This approach permits a enough wide variety of compensating branches to establish a exceptional and unique manage of reactive energy in electrical device.

In [8], from this above simulation results and waveforms it's miles finish that STATCOM is largely compact tool for keeping the voltage balance of the system.

In [9], the Simulink as properly the records from the cloud has been computed for identity of an expansion of load to be distinguished in specifically crucial and non-critical load. The simulation consequently enables in selecting the burden for consideration to be close down at some stage in the peak load and as a consequence will shave off the height. This will result in the balancing of the load during top hours and as a result will appeal to incentives.

In [10], this paper the grid-related PV electricity machine with high voltage profits. The proposed PV machine hired in two tiers, First excessive step-up ZVT-interleaved boost converter with winding-coupled inductors and lively-clamp circuits. By selecting the accurate turn's ratio of winding-coupled inductors excessive voltage benefit may be executed. The proposed paintings additionally showcase and demonstrated the constant-country model of the converter. The output contemporary and dc bus voltage is maintained by way of the usage of full-bridge inverter with bidirectional energy drift in the second one degree. The MPPT method improves the overall performance of the machine.

In [11], a method for stabilization the DC microgrid based on the state feedback is proposed in order to improve the stability of DC microgrid. By introducing the state feedback signal, this method increases the damping of the system and ensures the stable operation of the whole DC microgrid. The feasibility and effectiveness of this method are verified by the simulation results.

Paper [12] presents the arrangement of a low complexity Fuzzy Logic Controller of only 25-rules to be introduced in an Energy Management System for a private organization related microgrid including Renewable Energy Sources and limit capacity. The structure expects that neither the unlimited age nor the pile demand is controllable. The essential target of the design is to restrict the cross section power profile fluctuations while keeping the Battery State of Charge inside secure purposes of imprisonment. Instead of using assessing based methods, the proposed approach uses both the microgrid imperativeness speed of-progress and the battery SOC to extend, decrease or keep up the power passed on/devoured by the mains. The regulator plan boundaries (interest limits and rule-base) are changed by update a pre-described arrangement of significant worth rules of the microgrid direct. An assessment with various suggestions searching for a comparable goal is presented at the amusement level, while the features of the proposed structure are probably taken a stab at an authentic private microgrid completed at the Public University of Navarre.

In [13], the unique power and the responsive control of the force of a (BESS) Battery imperativeness amassing system using the cushy reasoning control to keep up rehash and the consistent quality of voltage of the Islanded Micro-organization. The fundamental level of the familiar paper is with considering the adequacy of the Battery imperativeness storing system regulator in setting on changes of rehash/voltage introduced to an aggravation happening in the islanded scaled down scale grid. In the islanded more limited size grid system, the power is produced using viable power source resources (RESs), i.e., sun and hydro-based PV. The use of these ideal significance sources has changed into the rule issue, imagining the yield control weaknesses from practical power sources. Further, power weakness raises control quality issues and prompts control disappointment. To beat such issues, the proposed soft reasoning regulator (FLC) approach is related with the BESS regulator to drive the trustworthiness of the islanded Micro-organization. The re-enactment result addresses that both the control approaches permit the unique immovability of the limited scale system and the upkeep of rehash and the voltage inside agreeable reaches. As such, the proposed BESS soft reasoning control isn't a ton as slanted to powerlessness as the BESS fiery control.

In [14], a novel imperativeness of the chief's system with two working horizons is proposed for a private limited scope framework application. The scaled down scale network utilizes the energies of a photovoltaic (PV), an energy segment, and a battery bank to supply the close by loads through a blend of electric and appealing vehicles. The proposed scaled down scale network works in incalculable cross section related and off-structure movement modes. The essentialness of the chief's structure joins a long stretch data assumption unit reliant on 2D powerful programming and a passing soft regulator. The long stretch assumption unit is planned to choose the reasonable assortment extent of the battery state of charge and power gadget state of hydrogen. The efficiency execution of the limited scale system parts, foreseen essentialness age and solicitation, imperativeness cost, and the structure goals are thought of. The resultant data by then is shipped off the transient fleecy regulator which chooses the action strategy for the limited scale grid subject to the constant condition of the scaled down scale network segments. A model of the proposed more limited size network including the essentialness of the chiefs' system is made, and exploratory tests are coordinated for three unmistakable imperativeness the heads' circumstances. The proposed organization strategy is endorsed through imperativeness transport and cost assessment.

In [15], MATLAB/Simulink is used to make and complete the microgrid test seat and FIS. The proposed method is attempted against a standard-based control procedure. Reenactment believes were finished on the made model and results have exhibited that the proposed FIS can enough decrease the change and draw out the presence pattern of the ESS.

III. Proposed System

Block diagram of proposed system is shown in Fig. 2, including wind turbines (WTs), PV arrays, ESD, AC load, and DC load. In the islanded operating state, the B-DC connected to the ESD uses a DC voltage droop control system. The converters used in WTs and PV arrays are regulated to track the maximum power points for improving energy utilisation. The AC load converter operates in a constant power control mode. In addition, the DC loads directly connected to DC buses can be regarded as resistive loads.

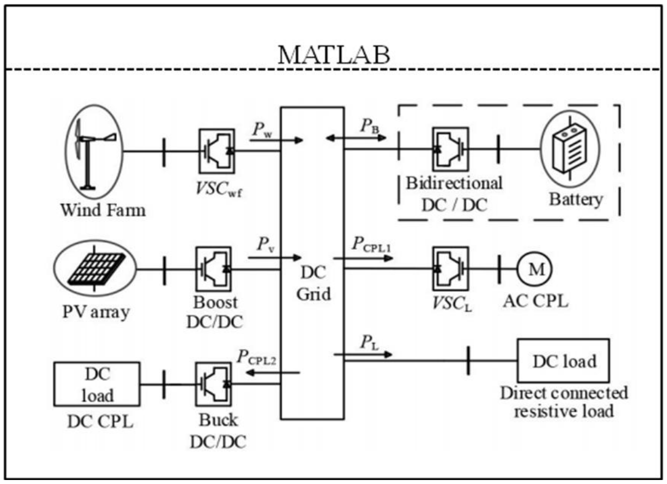

Fig 1 block diagram of proposed system

If the DC voltage oscillates during transient events, the (energy-storage device) ESD can reduce the oscillation by adding the oscillating voltage and current feedback loops. Moreover, the duty cycle is considered as an adjustable control parameter. The additional signal of feedback loop is expressed as follows:

$$\Delta d_D = k_{di}\Delta I_B + k_{du}\Delta U_{dc} \tag{1}$$

where kdi is the current-feedback coefficient. kdu is the voltagefeedback coefficient. ΔdD is the feedback duty cycle.

After introducing the state-feedback loop, the complex duty cycle ΔdB of B-DC can be expressed as follows:

$$\Delta d_B = \Delta d'_B - \Delta d_D \tag{2}$$

According to (2), the proposed damping control produces duty cycle ΔdD only when the system oscillates. If the duty cycle is treated as a new control parameter, the state matrix of power grid can be transformed as follows:

$$A'_0 = \begin{bmatrix} a'_{11} & a'_{12} \\ a'_{21} & a'_{22} \end{bmatrix} \tag{3}$$

Where

$$a'_{11} = -\left[R_B + k_{di}\left(U_{dcr} - \frac{k_B U_{dc0}}{R_L} - \frac{k_B P_{LS}}{U_{dc0}}\right)\right]/L_B;$$
$$a'_{12} = k_B(1-d_{B0})/L_B R_S - k_{du}\left(U_{dcr} - \frac{k_B U_{dc0}}{R_L} - \frac{k_B P_{LS}}{U_{dc0}}\right)/L_B;$$
$$a'_{21} = [(1-d_{B0}) + k_{di}I_{B0}]/C.$$
$$a'_{22} = (k_{du}I_{B0} - 1/R_S)/C; \tag{4}$$

The characteristic polynomial of the state matrix is given as

$$f(s) = s^2 - (a'_{11} + a'_{22})s + (a'_{11}a'_{22} - a'_{12}a'_{21}) \tag{5}$$

By introducing damping control, the attenuation coefficient of DCpower grid can be obtained using

$$\alpha' = -(a'_{11} + a'_{22})/2$$
$$= \frac{R_B + k_{di}\left(U_{dcr} - \frac{k_B U_{dc0}}{R_L} - \frac{k_B P_{LS}}{U_{dc0}}\right)}{2L_B} + \frac{1/R_S - I_{B0}k_{du}}{2C} \tag{6}$$

According to (6), the variation in attenuation coefficient can be calculated as follows:

$$\Delta\alpha = \alpha' - \alpha_0 = \frac{k_{di}}{2L_B}\left(U_{dcr} - \frac{k_B U_{dc0}}{R_L} - \frac{k_B P_{LS}}{U_{dc0}}\right) - \frac{I_{B0}k_{du}}{2C} \tag{7}$$

If Δα>0, the additional state-feedback loop can cause the eigenvalues of DC-power grid to shift to the left, enhancing the DC voltage damping. Therefore, the feedback coefficients kdu and kdi can be satisfied as follows:

$$k_{di} > \frac{I_{B0}L_B}{\left(U_{dcr} - \frac{k_B U_{dc0}}{R_L} - \frac{k_B P_{LS}}{U_{dc0}}\right)C}k_{du} \tag{8}$$

The variation scope of feedback coefficients kdi and kdu can be limited using (8), ensuring that the proposed control loop always produced positive damping. In the proposed control system, state variables IB and Udc are used to provide the feedback signals, both of which are then added to the output duty cycle of droop control. After disturbance occurs in a DC-power grid, by detecting the changes in IB and Udc, the additional duty cycle ΔdD generated by the feedback loop can provide a new function to decrease the voltage oscillation. In the steady state, the damping controller will not produce additional steady-state error because its output is zero. If the system steady-state point changes, the steady-state error produced by the additional damping controller is eliminated by using the PID controller.

IV. SIMULATION & RESULT

The MATLAB simulation diagram of proposed optimized damping control of islanded dc power systems is shown in fig 4.1 which employs proportional-integral-derivative (PID) controller using state feedback. Simulation is divided into 4 parts: PV module, battery, DC to DC converter and bus system.

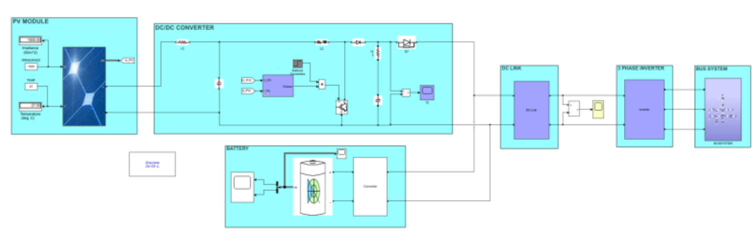

Fig 2 simulation diagram

Different parameters of PV module are actual irradiance 1000.00, reference irradiance 1000, actual temperature 27°C and reference temperature is 27°C, actual values are

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compared with reference values and are controlled in such a way that maximum power can be achieved.

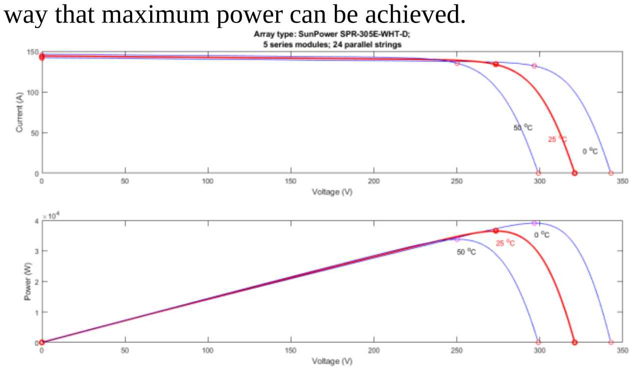

Fig 3 output of solar

Fig 3 shows output values from solar panel; here we used SunPower array type with 5series and 24 parallel strings.

Output of solar panel is fed as input to converter system, this part convert input DC into desirable level of DC. RC filter (it is a Low pass RC filter, again, passes through low-frequency signals, while blocking high frequency signals) is followed by inductor (it allows only dc components to pass and blocks ac signals), for filtering out ripple from power. Here actual value of voltage and current is compared with desirable values; switch controls flow of voltage (fig 4.1). Voltage measurement of DC-DC converter is shown in fig 4, initially there are some glitches after 0.05sec we get clean DC output of 190V, here setting time is 0.05s.

Fig 4.output of DC-DC converter

Converter in battery part converts and step down voltage to desirable value (12V) and charge battery. Battery parameters like voltage, current and temperature are shown on scope. Output of battery is shown in fig 5.

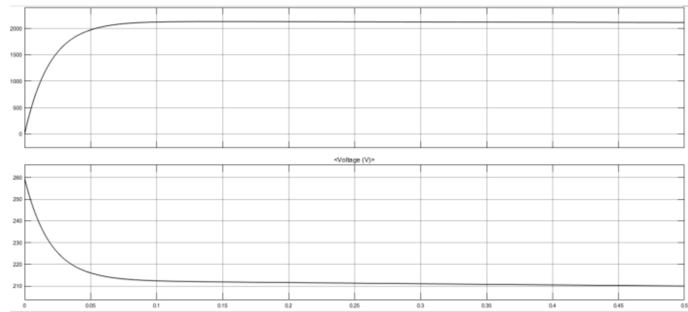

Fig 5 battery output

IV. Conclusion

In aim to the stability problem of the DC microgrid which was caused by the CPLs, the state feedback technique was introduced. This technique was used to counteract the destabilizing effect of the CPLs by adding the state feedback signal to the duty cycle of the source converters, so as to realize the stability of DC microgrid. This method only need use the signal of DC bus voltage, and the realization is simple. The validity of the proposed method has been verified by simulation experiments. In a DC power system, voltage oscillation probably occurs because a constant power control applied to the VSCs exhibits a negative impedance characteristic during the dynamic process. According to the eigenvalues analysis, conventional voltage droop control cannot damp the voltage oscillation. As a result, the stability margin remains insufficient in the DC power grid. In the proposed control scheme, both DC voltage and DC current are used as state-feedback signals, and the duty cycle of converter can be regulated by the two state feedback loops, which are attached to the output of inner PID controller. According to the pole placement analysis, the eigenvalues of DC power system can be assigned using the proposed feedback loops.

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