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LVRT Control Strategy for Three-Phase Grid Connected PVSystem

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***Abstract*— With increasing interest in Photo Voltaic systems in the international market, proper protection system implementation is required in the grid-connected PV System. Traditionally it is seen that a grid-connected PV system is discontinued during a transient fault period to protect the inverter from power imbalance between the PVside and the grid side. This paper presents a Low Voltage Ride Through control strategy for the system to continue supplying to the grid even during fault conditions. The low Voltage Ride Through strategy is achieved by adding a discharge circuit to the DC-link of the inverter and modifying the id and IQ current reference to the inverter when grid voltage sag occurs. A 50 KW two-stagephotovoltaic system model is designed in MATLAB platform with a PV array, Boost Converter, 3-phase DC/AC inverter, filter, and the grid. Maximum power point tracking(MPPT) control scheme is adopted in Boost Converter to track maximum power in our system, and for the control, the inverter hysteresis band control strategy is employed. A separate discharging circuit was adopted on the dc side forLVRT operation. Simulation results using MATLAB verifies the validity of the proposed control strategies under symmetrical voltage sag conditions.**

***Keywords* — Maximum Power, Discharge Circuit, Hysteresis band, Voltage sag**

I. INTRODUCTION

With the world facing serious environmental issues, the conceptof clean energy is taken into account to remodel the energy sector of the world. Being one of the major sources of renewable energy PV power generation is getting major consideration. Consequently, the impact of PV systems on grid performance must be studied for the grid-connected PV System, so that the system meets the grid code requirement and better performance is ensured. In a grid-connected PV, the system must have Low Voltage Ride Through (LVRT) capability when the grid undergoes faulty conditions. To understand the LVRT, let's study a curve as shown below;[1]

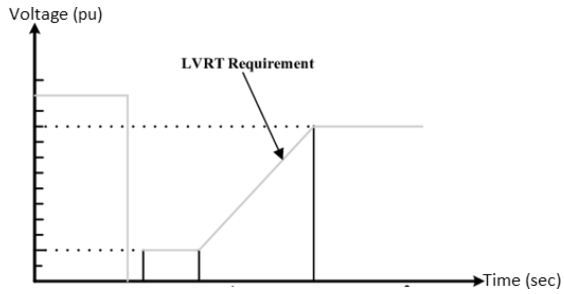

Figure 1: Typical LVRT curve

Figure 1 shows a typical LVRT curve. From this curve, we canobserve that the PV System is to be isolated from the grid when the depth and duration of voltage sag are below the LVRT curve. During any transient fault, when voltage sag occurs, if the system is to be kept connected to the grid, the system must compensate a certain amount of reactive power according to the depth of the sag to support grid voltage recovery. In addition, during this fault period, an imbalance occurs between the input and output side of the boost converter resulting in dc-link overshoot which may cause exceed in Imax of the inverter. So,the system is required to have a better corresponding protectioncontrol strategy.

Recently many literatures have inquired about the LVRT capability in grid-connected PV Systems. A significant number of works are devoted to incorporating LVRT capability in large-scale PV so that it does not trip off during system disturbances. Fuzzy-based real and reactive power control methods have beenused in [2] comprising overcurrent control and reactive current injection based on active power reference calculation and grid code respectively along with feedforward control is implemented to enhance the FRT capability of the PV system.

For three-phase systems, the presence of positive- and negative- sequence voltages/currents under grid faults should be properly handled, which in return also provides much flexibility for power injections during LVRT. A peak current limit control scheme that can inject the required current and negative sequence current was employed in [3]

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also to suppress the negative sequence grid voltages during LVRT. In [4] a simple proportional controller is designed according to the voltage saglevel and inherent power-voltage characteristics. In [5] a hybridcontrol method composed of software and hardware is adoptedto upgrade the capacity of LVRT.

II. **PROPOSED SCHEME**

A discharge circuit can be added such that the id and iq currentreference can be adjusted in the system to obtain the low voltage ride-through operation. A basic system Block diagram is shownin figure 2 below;

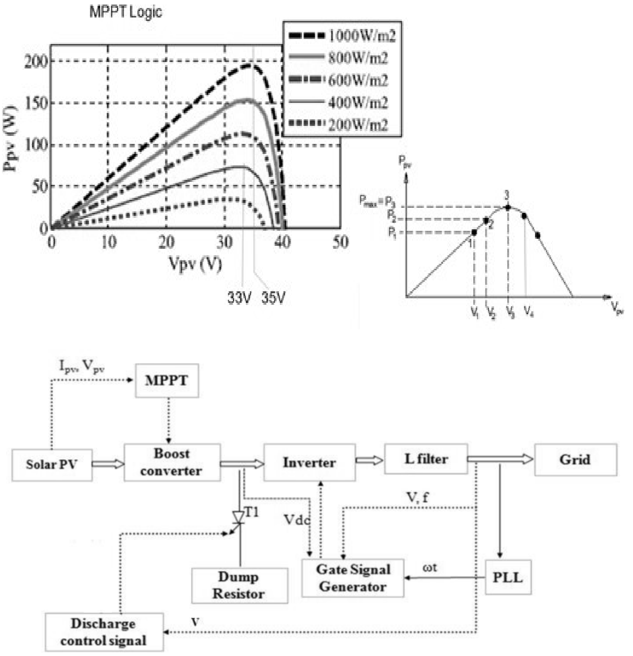


Fig. 2 Overall Scheme the proposed scheme

In the system, the obtained output power from PV is passed through a boost converter to boost the voltage and operate at the voltage at which PV-Panel generates Maximum Power for a particular irradiance. Here MPPT controller is used to generateswitching signals for the boost-converter to track the maximumpower point at which PV gives maximum power. Then the output of the boost converter so obtained is passed through a three-phase inverter to get three phase output and it is synchronized to the grid through L filter at 400V.

Here PLL is used to sense the grid frequency continuously and the Inverter is designed such as to operate at grid frequency. During any transient fault, the grid voltage drops. This is sensed by the voltage sensor and PV is shifted from MPPT operation to LVRT operation.

During the fault condition, dc-link voltage overshoot may occur resulting in a power imbalance. So, a DC braking chopper is introduced in this paper to dump the excess power to reduce the overshoot in dc link voltage. The current overshoot in the grid side during fault is reduced by the modified id and iq reference current.

III. MODELING OF PROPOSED SCHEME

A. Boost Converter and MPPT

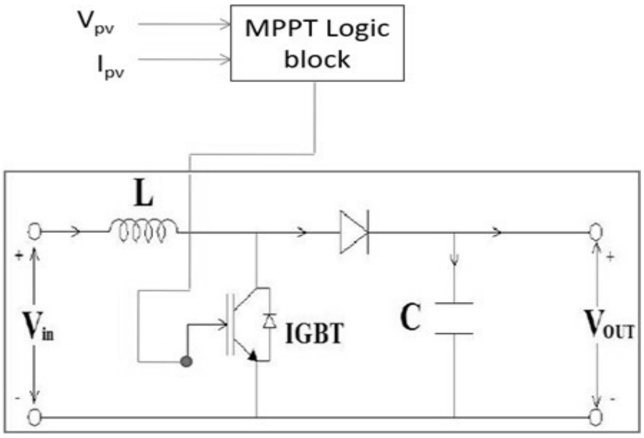


Fig 3. Boost Converter

Boost Converter steps up the voltage to a particular voltage at which maximum power is obtainable from the PV panel. MPPTlogic controller is used to generate a base signal for the IGBT switch to extract Pmax from the PV panel.[6]

For Maximum Power Tracking, Perturb and Observe algorithm is used. In this technique, when a minor perturbation is introduced in voltage, it causes the power variation of the PV module as shown in P-V curves. The PV output power is periodically measured and compared with the previous power. If the output power increases, the same process is continued. Otherwise, perturbation is stopped at the previous point. For example: starting from V_1, Power increases up to perturbed value V_3 and power decreases at the next perturbed value of V_4.

Therefore, V_{dc} has to be controlled at V_{max} to ensure that maximum power is extracted. If Power injected into the Grid isless than Pmax from the PV panel, then the capacitor gets charged, and V_{dc} increases. If Power injected into the Grid is more than P_{max} from the PV panel, then the capacitor gets discharged and V_{dc} decreases. Therefore, if V_{dc} is controlled to V_{max}, then Power injected to Grid will be equal to P_{max}. Hence, V_{dc} is measured and compared with V_{ref} which is equal to

Vmax. The error so obtained is passed through the PI – controller. PI – controller gives I_d (ref) proportional to P_{max}

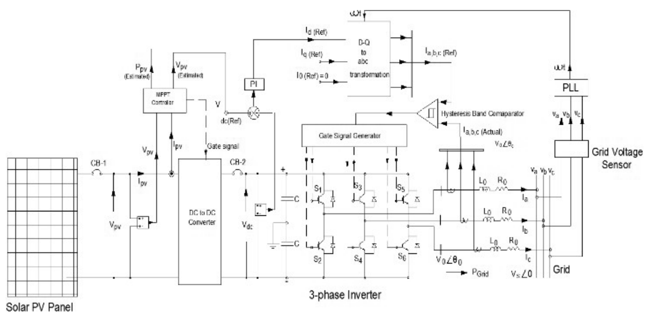


Fig.4 3-phase Inverter with Hysteresis Band CurrentControlled

Technique

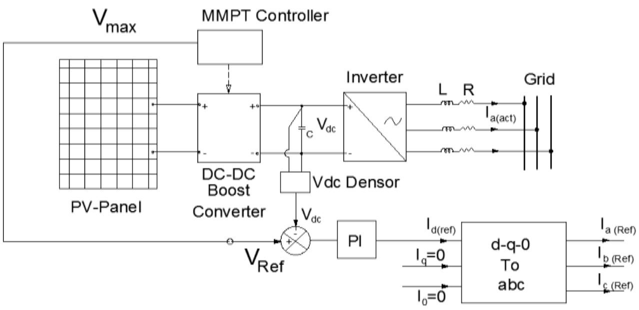


Fig.5 Closed loop control to generate Id (ref)

B. Hysteresis Band Controller

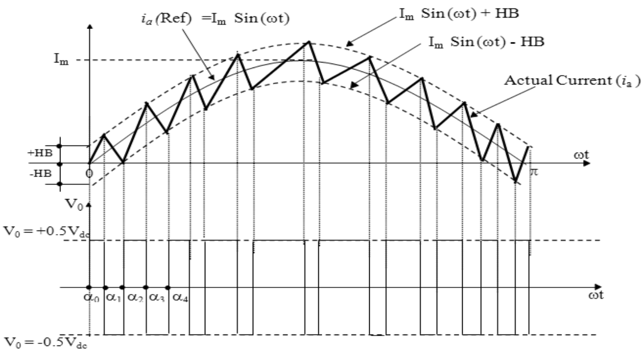


Fig.6(a) Theory of Hysteresis Band Current Controller

$$+0.5V_{dc} - v_s = R_0 . i_a + L_0 \frac{di_a}{dt}$$

$$-0.5V_{dc} - v_s = R_0 . i_a + L_0 \frac{di_a}{dt}$$

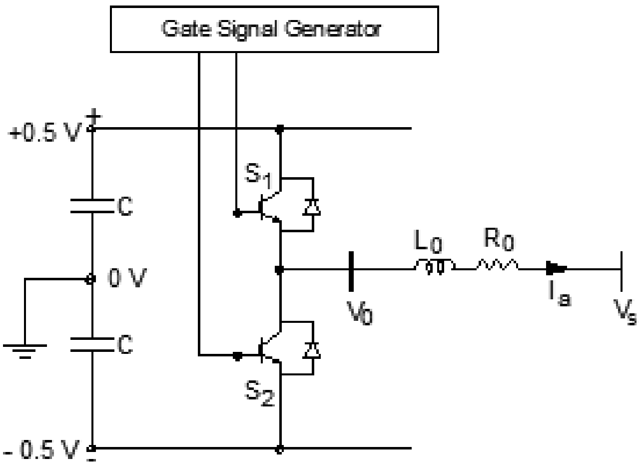


Fig.6(b) Theory of Hysteresis Band Current Controller

The hysteresis band controller forces the output current of the inverter to track the reference signal within a constant set hysteresis band.

Hysteresis control is the simplest control loop to implement that operates the system in either of two states: off or on. In hysteresis control, the hysteresis band is defined, and if the feedback signal is above that band, the plant is operated in one state, say ON state and if it is below that band it is operated in the other state, say OFF state. If the feedback is within the band,the operating state is left unchanged.

In the hysteresis controller, as shown in figure 6(a), if the errorbetween the actual current (i) and the command current (i*) is more than the pre-set value h (called hysteresis band), then thestate of the switch is changed to reduce the error. In other words, the state of the switches is changed whether the actual current is greater or less than the command current by the hysteresis band

- $i^* - i \leq -h$: lower switch S− is turned on to decrease the load current by producing a negative voltage (−1/2Vdc)
- $i^* - i \geq h$: upper switch S+ is turned on to increase the load current by producing a positive voltage (1/2Vdc)

C. Low Voltage Ride Through (LVRT)

The basic idea of LVRT is to cause the PV system to remain interconnected even during the transient fault by injecting reactive current by the inverter to reduce the current overshoot at the grid side and reducing the dc link voltage overshoot by using a dc braking chopper.

During a transient fault condition, the system is switched from MPPT mode to LVRT mode. In LVRT mode, the inverter supplied the active current i_d and reactive current iq. This current is the maximum current supplied by the inverter. No active power is transferred to the grid so excess power is dumped into the in-dump resistor. when this value of reactive current is supplied by the inverter to the grid it suppresses the current overshoot on the grid side. [1] [2]

D. DC Braking Chopper

DC Braking Chopper is a power electronics circuit that is usedto dump the power to reduce the overshoot in dc link voltage during a transient fault in the transmission line.

During a transient fault in a transmission line, no active power is transferred to the grid so this excess active power is dumpedin the dump resistor.

It consists of an IGBT switch and resistor. The value of the resistor is calculated by $R = V^2 / P$.

And the IGBT switch is controlled by a gate signal.[2]

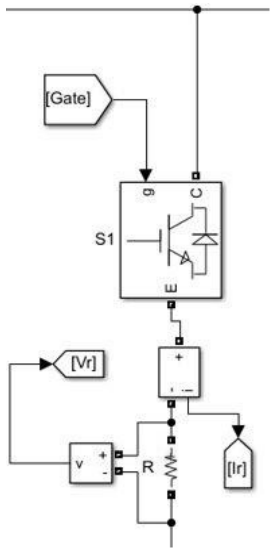


Fig.7 DC Braking Chopper

IV. SIMULATIONS RESULTS

In this section, findings carried out by a simulation model based on MATLAB/SIMULINK that represent the dynamic behavior of PV systems during short-term grid disturbances are presented. Figures 9 represent the simulation result before implementing the LVRT strategy during the transient fault. Figures 10 represent the simulation result after implementing the LVRT strategy during transient fault. After implementation of the LVRT strategy, the excess energy is dumped into the ballast load as in figure 10(b). During the fault period inverter has provide reactive power to stay connected to the grid as in figure 10(f).

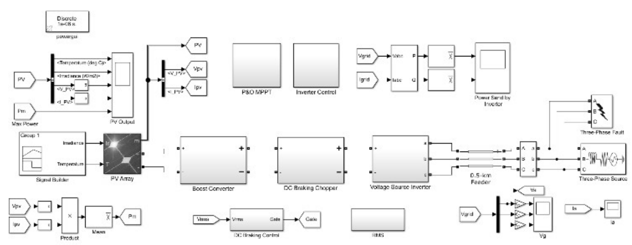


Fig.8 50kW PV model with symmetrical fault

During fault

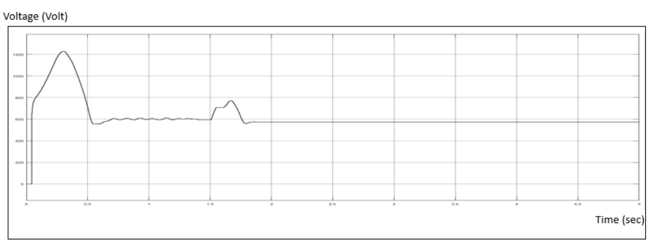


Fig. a Plot of DC-Link voltage V_{dc}

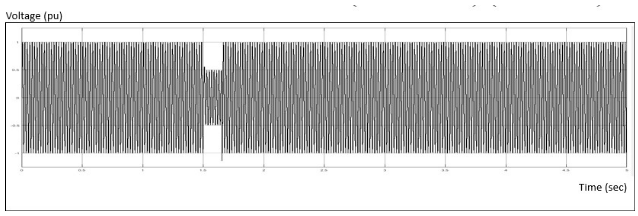


Fig. b Plot of grid voltage (PU)

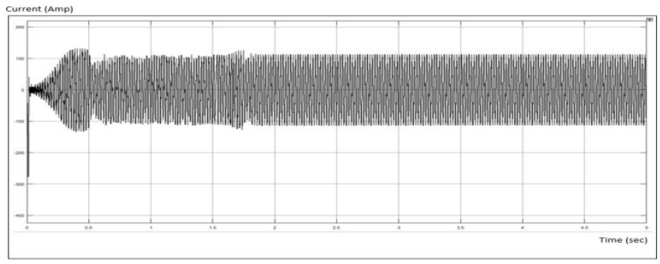


Fig. c Plot of per phase current Ia

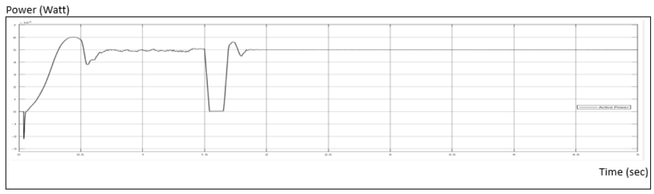
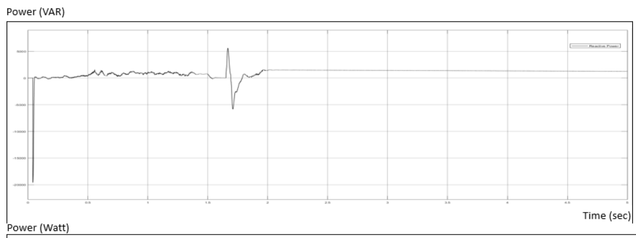


Fig.d Plot of active power injected into the grid



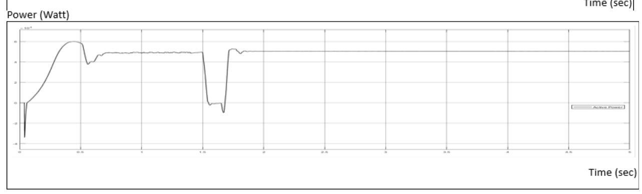


Fig. e Plot of reactive power injected into the grid

Fig.9 Simulation result before implementing the LVRTstrategy during the transient fault

With LVRT

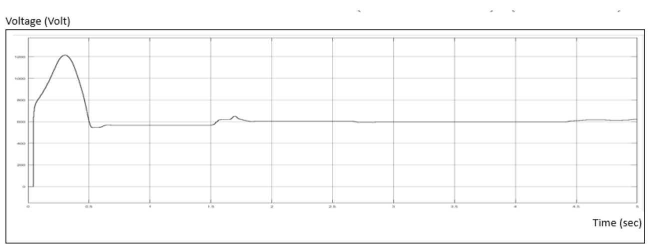


Fig. a Plot of DC-Link voltage Vdc

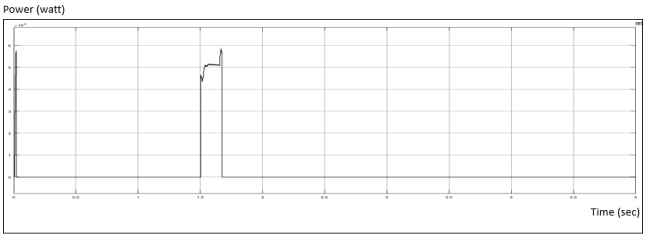


Fig. b Plot of power dump in DC ballast

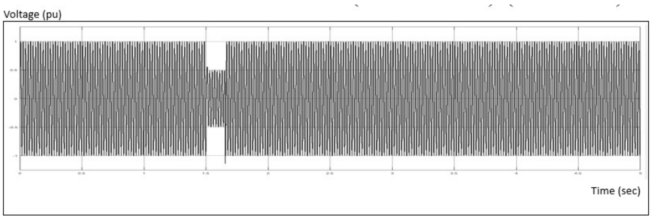


Fig. c Plot of grid voltage (PU)

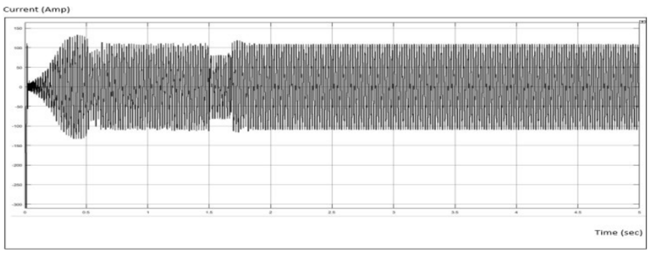


Fig.d Plot of per phase current I_a

Fig. e Plot of active power injected into the grid

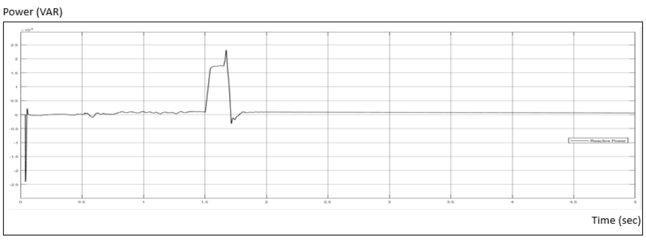


Fig. f Plot of reactive power injected into the grid

Fig.10 Simulation result after implementing the LVRTstrategy during transient fault

V. CONCLUSION

With the use of the LVRT strategy by introducing the i_q and i_d loop and by introducing the breaking chopper circuit in the system we observed our required result. The overshoot in current and the dc-link overshoot was found to be reduced. Hence, we developed a 50 KW two-stage photovoltaic system with an LVRT control strategy. The simulation of this system was done in the MATLAB Simulink platform. In simulation studies, a symmetrical fault is applied to verify the effectivenessof the proposed control strategy, which shows that the overshoot in the current is suppressed and the dc-link voltage overshoot is also reduced and the system now does not require to be disconnected from the grid.

VI. REFERENCES

[1] Lihua Li, Hong Zhou, Fuqiang Luo, XiangyangLiin, Yang Han "Control Strategy for Low Voltage Ride Through (LVRT) Operation of Two-Stage Photovoltaic Power Generation System", 2018, IEEE

[2] Mr. Pranav Chandran, Ms.R.Sai Madhura, Dr.J. Preetha Roselyn, Mr. Anirudhh Ravi, Mr. Varun Gopal, Dr. D. Devraj, "Development of Intelligent Fuzzy PQ-FRT Control Strategy for Grid Connected Solar PV System", 2019, IEEE

[3] Hsin-Chin Chen, Chia-Tse Lee, Po-Tai Cheng, Remus Teodorescu, Frede Blaabjerg, "A Low Voltage Ride Through Technique for Grid-Connected Converters with Reduced Power Transistors Stress, 2015, IEEE

[4] Yongheng Yang, Ariya Sangwongwanich, Hongpeng Liu, Frede Blaabjerg, "Low Voltage Ride Through of Two-StageGrid Connected Photovoltaic Systems Through the Inherent Linear Power Voltage Characteristic",2017, IEEE

[5] Tingyue Jiang, Ruoyu Song, Jianguo Jiang, Tao Yu," Research on LVRT Based on Maximum Power Tracking Strategy", 2017, IEEE

[6] GAGA Ahmed, ERRAHIMI Fatima, ES-SBAI Najia, "Design and implementation of MPPT solar system based on the enhanced P&O algorithm using Lab view", IEEE