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HYDRO/PV HYBRID POWER SYSTEM WITH NEW CONTROL STRATEGY TO MITIGATE THE VOLTAGE DISTURBANCES

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ABSTRACT

This paper presents a new control strategy for grid integrated hydro/PV hybrid system. Under grid connected mode, the control strategy will work as a constant current controller (CCC) to inject the specific quantity of power generated by micro-grid system and provide robust tracking of generated active and reactive power trajectories. As the fault transpires in electrical power system, the power grid must be disconnected from rest of the micro-grid system to avoid potential hazard and this situation is identified as islanding. In islanding mode of operation, the proposed control strategy switch to constant voltage controller (CVC) for maintaining constant voltage at the point of common coupling (PCC) to feed local sensitive load. The hydro and PV systems are considered in this paper as micro-grid system, which are hybridized for injecting generated power to main grid. The transient and steady state analysis, stability analysis of the proposed grid integrated hybrid system is performed to realize the improved performance of the system. The harmonic analysis is also done to prove the improved power quality of the system. The presented results clearly indicates the control strategy has full control over the active and reactive power flow to/from the hybrid system and proposed system is more effective, reliable, less complex, have higher power quality and better dynamic performance under most severe fault conditions.

Keywords - *PV system, Pico-hydro System, Hybrid System, Power grid, Rural Electrification*.

1. INTRODUCTION

Renewable Energy Sources (RES) are gaining more attention because of threatened limitations of the conventional sources such as production of harmful emissions, causes global warming, greenhouse effects, and acid rain and future shortage in fossil fuels [1]. The bottleneck of renewable energy are that it is difficult to generate large quantities of electricity as produced by traditional fossil fuel generators and reliability of supply as these systems often relies on the weather for its source of power. To defeat these difficulties of RES system, either RES system can be integrated with the power grid or two or more RES systems can be hybridized to provide continuous power supply and to fulfill demanded power supply. Hybridization of renewable sources via common DC bus of a power converter has been prevalent because of easy integration monitoring and control as compared with a common AC bus. There are some related works on common DC bus based hybrid systems [2-6].

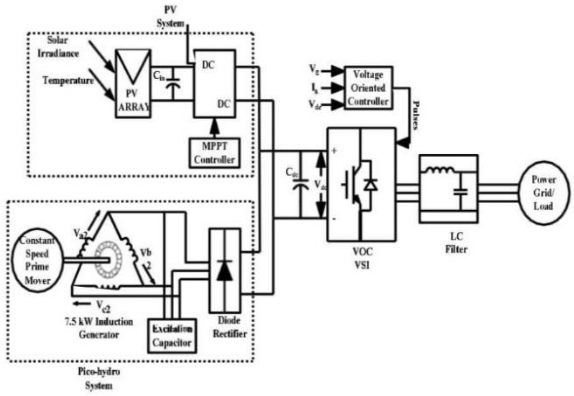
Recently, new trends in power electronic technology for integration of RES systems have undergone a fast advancement because of two factors. The first factor is advancement in fast semiconductor switches which are proficient for rapidly switching and capable for handling high powers. The second factor is the innovation and development of real time controllers that can execute advanced and complex control algorithm. Because of advancement in power electronic interface, it is highly preferred for connecting RES systems to the power grid in order to make significant impact [2]. Most of the RES systems generally have variable DC voltage as an output. Hence, DC/AC converters are in trend as a power electronic interfacing device for grid interaction with variable-voltage DC sources. The Voltage Source Inverter (VSI) based interface has been developed to convert a variable DC voltage to a nearly constant AC voltage at the utility line frequency with high-quality power [7-9].

The control of grid-side converter is an essential part to maintain constant DC link voltage at a specified value and to keep the unity power factor. The current controllers for controlling the grid connected VSI plays dominant role for feeding a grid with high quality power. The stationary reference frame proportional integrator (PI) is generally implemented for grid connected current controlled inverters. Such types of controllers are very simple and have easy operation, but they have large steady state tracking errors for AC current regulation [10]. The synchronous frame PI controller reduce the steady state tracking error up to zero, provide low current ripples and good sinusoidal waveform, but this controller requires multiple reference frames and also arises computation complexity [11-13]. Recently developed proportional resonant (PR) controller has better performance as compared with synchronous frame PI controller for achieving good steady state and transient performance. The PR controllers also provide smooth operation for both single phase and three phase inverters [14-17]. A nonlinear control algorithm known as Direct Power Control strategy (DPC) is classical control method for controlling grid connected converters. The DPC strategy has no inner current control loop and no Pulse Width Modulation (PWM) block. The switching states of converter are determined by a switching table. The DPC generates voltage vectors and determines duty cycle in every sampling period for calculating instantaneous active and reactive power demand [18-19]. Today, the Voltage Oriented Control (VOC) is popular and constantly being developed and improved for grid connected converters. The algorithm decuples the 3-ϕ grid currents into d-axis and q-axis components and the active and reactive power is achieved via internal current control loop. This algorithm uses conventional PI controller in rotating reference frame for producing control signals for PWM generator. The VOC control technique has high dynamics and static performance [20-23].

Hence, in this paper, a new control strategy is described and implemented for grid connected and islanding mode of operation. During grid connected mode, the control strategy will work as constant current controller to inject the preset amount of power to grid and in islanding mode, the strategy will work as constant voltage controller to control maintain constant voltage at PCC to connected local sensitive load. For the small hydro system, Self Excited Induction Generator (SEIG) preferred as it is more advantageous over the synchronous generator. The PV system and hydro hybrid system is hybridized via common DC bus for reducing control complexity and cost of the system.

2. SYSTEM CONFIGURATION AND OPERATION

Fig. 1 depicts the schematic diagram of the PV/Pico-hydro hybrid system, which is integrated with the power grid The proposed system is configured by the PV array, DC/DC converter controlled by MPPT controller, Self Excited Induction Generator (SEIG), excitation capacitor for the initial excitation of SEIG, diode rectifier, grid interfacing voltage source inverter (VSI), Voltage Oriented Controller (VOC) and LC filter. Generated AC voltage of the Picohydro system is converted into the DC via diode bridge rectifier and linked to the DC voltage of the PV system to form DC bus.



The DC power requirement of the consumer is fulfilled by the DC bus. Fig. 1. Schematic diagram of PV/hydro hybrid system integrated with the power griBoth the PV and hydro systems are intermittent in nature and cannot generate the constant power. To improve the performance and reliability of the proposed system, the SEIG is driven by the constant speed prime mover to generate the constant 7.5 kW power. The PV system generates the variable power due to variation in solar irradiance and temperature. Hence, to fulfill the power requirement of community the power grid is integrated to the hybrid system. The connectivity of the grid with hybrid system will be there, if the hybrid system is unable to fulfill the power demand. If generated power of the hybrid system is able to fulfill the power demand, then the hybrid system will be in islanded mode. The feature of anti islanding is provided by the VOC VSI.

3. CONTROL STRATEGY FOR HYBRID SYSTEM

Fig. 2 depicts the configuration of proposed advanced PV/ hydro hybrid system integrated with power grid. To integrate hybrid system with power grid, a PWM VSI is used as an interfacing device. To control this interfacing inverter for grid connected Power Generating systems, a smart controller is required that can maintain the constant output voltage at the point of common coupling (PCC) under different possible conditions such as connection/disconnection of grid and solar

irradiance/hydro energy variation. For grid connected mode, the controller will be operated as a constant current control mode for supplying specified power to the grid. When hybrid system is cut off from the main grid, controller must detect this islanding situation and change to voltage control mode and hybrid system will provide constant voltage to a part of consumer load as per the capability. Hence, for controlling the interfacing inverter to operate either in grid connected mode or islanding mode, the controller need to switch either to Constant Current Controller (CCC) or to Constant Voltage Controller (CVC).

The active and reactive power requirement can be expressed as the following eq.(1)

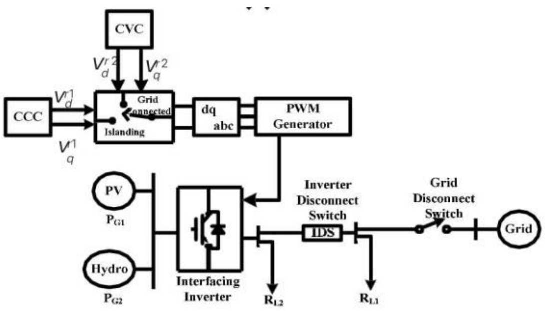
For grid connected mode, synchronization between the grid and hybrid system is an important issue, which is carried out by using 3-ф Phase Locked Loop (PLL). The PLL determines the frequency and phase angle of the PCC. For unity power factor operation, reference current signal must be in phase with the grid voltage. The controller is also designed to provide near unity PF operation of the system.

kW advanced SEIG based hydro system and this hybrid Hyderabad , India system is integrated with the power grid to insure continuous electrical power supply. The specifications and parameters of PV system, Pico-hydro system and interfacing inverter are given in Table I, Table II respectively.

TABLE I. Specifications and parameters for PV System

Quantity	Symbol	Value
PV Panel parameters		
Output power of PV panel	□□□	10 kW
DC Output Voltage	□□□	275-321 V
DC Output Current	□□□	10.9-33.02 A
Boost Converter parameters		
Switching Frequency	f□□	5 kHz
Capacitor	□□	15 µF
Inductor	□□	170 mH
MPPT Controller gain	□□□□	7.2

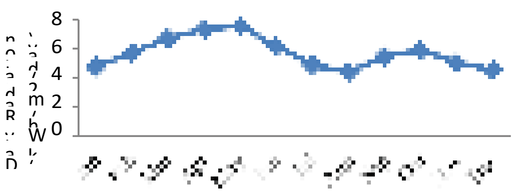
Quantity	Symbol	Value
Output capacity	□i□□	20 kW
Switching Frequency	f□	10 kHz
Output frequency	f	50 Hz
Filter inductance	□$_f$	8 mH
Filter Capacitor	□$_f$	56 µF
DC Link Voltage	□□□	500 V
DC link Capacitor	□□□	1200 µF
Grid voltage	□^{g} □□□(□)	230 V
Grid frequency	f	50 Hz



A. Hybrid System

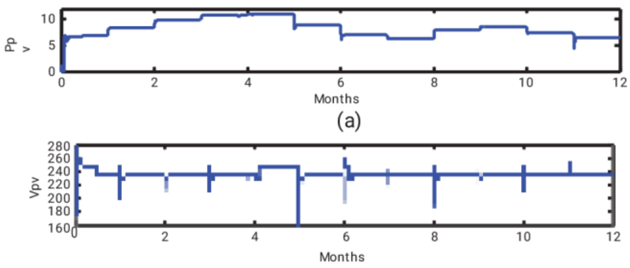
a) PV System:

The proposed system is tested for average monthly daily irradiance in kWh/m2/day as shown in the Fig.5
The average monthly power and voltage generation from PV panel is shown in the Fig. 6 with respect to solar irradiance given mentioned in Fig. 5.



Months

Fig. 5. Daily average solar radiation at Bhopal



(b)

Fig. 6. Variation of (a) power and (b) voltage generation of PV system wrt solar irradiance

b) Hydro System:

A 3-ϕ 7.5 kW, 415 V, 50 Hz, 4 pole, Δ connected induction machine is used as a SEIG for developing the hydro system. A 5 kVAr capacitor bank is connected across the stator terminal of the induction machine to generate the rated voltage and current. Fig. 7 shows the outputs of the SEIG i.e. generated voltage (Vh), current (Ih), power (Ph), frequency (fh) and phase angle (ωt). The SEIG takes 0.32 s to build up the rated voltage.

The hydro system generates AC quantity, which cannot be integrated with the DC quantity of the PV system. Hence, generated AC quantity of the Pico-hydro system is converted into a diode bridge rectifier with LC filter (4.2 mH, 56 µF). The DC quantity of both the PV system and Pico-hydro system is hybridized and form common DC link bus with 500 V. The DC load may be supplied by this DC bus.

B. Interfacing Inverter

The solar irradiance is variable. Hence, a space vector pulse width modulated (SVPWM) VSI has been used in this paper with 10 kHz switching frequency with output voltage has rating 230 V, 50 Hz. A low pass filter with LC element (3.5mH, 48 µF) is connected between interfacing inverter and isolation transformer for smooth and clean power injection. Fig. 8 shows phase voltages of interfacing inverter filtering. Fig. 9 shows the inverter phase voltage to be injected to the power grid with LC filter.

After completion of synchronization, the power grid be reconnected to hybrid system. Transients occur during will connection/disconnection of the grid. These transients recovered with in 0.015 s and after 0.815 s clean and are voltage at PCC will be available. smooth

4. CONCLUSION

In this paper, a control strategy for grid connected and islanding mode of operation of PV/Pico-hydro hybrid The proposed control strategy performs two interfacingsystem. control i.e. CCC for grid connected mode of operation and CVC for islanding mode of operation. The islanding technique is responsible to switch the mode of control.detection control strategy is able to remove transients during grid-The connection and islanding in 0.0115 s and 0.015 s respectively.

The developed hybrid system is simple and has the complexity. The system uses less number of switches, less the efficiency of the system is also high as switching losshence less. The reliability and power quality of the system isis improved because the control scheme has the full control the active and reactive power flow and has the betterover performance under the variation in the solar irradiance and load. Harmonic analysis of the proposed system has been performed and results demonstrate that the voltage THD is1.84% and current THD is 1.23%. The voltage and current THD % is less than 5%, limit imposed by the IEEE-519 standard. The proposed hybrid system has achieved near tounity power factor grid operation (average above 0.91), transient response (0.012 s) under all possible fast i.e. variation in solar irradiance and load demand andcircums ances also has high efficiency of about 94%. All the obtained system conclude that proposed system is feasible for small scale results electrification. Rural

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