

New Control strategy of Single-Phase Micro grid System Using Renewable Energy Based Generation

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ABSTRACT

This paper presents an adaptive sliding mode control (ASMC) of an improved power quality standalone single phase micro grid system. The proposed micro grid system integrates a governor-less micro-hydro turbine driven single phase two winding self-excited induction generator (SEIG) with a wind driven permanent magnet brushless DC (PMBLDC) generator, solar photo-voltaic (PV) array and a battery energy storage system (BESS). These renewable energy sources are integrated using only one single-phase voltage source converter (VSC). The ASMC based control algorithm is used to estimate the reference source current which controls the single-phase VSC and regulates the voltage and frequency of the micro grid in addition to harmonics current mitigation. The sliding mode control is used to estimate the reference real power of the system to maintain the energy balance among wind, micro-hydro, solar PV power and BESS, which controls the frequency of standalone micro grid. Proposed micro grid shows that the grid voltage and frequency are maintained constant while the system is following a sudden change in loads and under intermittent penetration of wind and solar energy sources. Harmonics are mitigated with fuzzy logic controller in this paper. Results are verified through MATLAB/SIMULINK environment.

I. INTRODUCTION

The benefits of an integration of renewable energy sources like wind, solar and micro-hydro with BESS (Battery Energy Storage System) are currently well recognized. The function of micro grid as controlled entities explores the possibility of coordinating standalone renewable energy sources so that they behave as a single producer of electrical energy to avail the full

advantages of renewable energy resources in a consistent and manageable way. The energy balance and system parameters control are the key features of the micro grid. In order to achieve proper integration of renewable energy sources (RES), the development of effective frequency and voltage control scheme is essentially desired [1] - [2]. The concept of micro grid is most interesting for successful dealing with the challenges in the integration of renewable energy sources [3]. A micro grid is having capability to operate in both standalone and grid tied modes operation depending upon the design of suitable control scheme [9] - [10]. The various derived forms of the micro grid such that virtual power plant, cognitive microgrid and active distribution system can be studied as a main constituent of smart grid [4] - [8]. In grid tied microgrid, the main grid supplies the deficit power and absorbs the surplus power in a grid tied microgrid in order to maintain power balance which in turn regulates the system frequency. Whereas, in a standalone microgrid, the balance of active and imaginary powers, is achieved using controlling the flow of power among different components of the microgrid [9] - [10]. An IEEE standard for interconnection of distributed energy sources are given in [11]. The voltage, frequency, real and imaginary powers are the main system variables required to control the operation of the microgrid [11]. BESS allows the large scale integration of intermittent energy sources [12].

Despite of its benefits, the capacity of BESS is not fully utilized in the microgrid system yet [13]. Power electronic control of integrated renewable systems has been discussed extensively in [14] - [15]. A comprehensive review of control of power electronic converters used in microgrid is presented in [16]. The main challenge in control of standalone microgrid includes the balance of powers and control of system voltage [17]. NABC and other control schemes of single-

phase SEIG feeding fluctuating loads is reported in [18-22]. The comparison among photovoltaic array maximum power point tracking techniques are discussed in [23]. In this project, the design and implementation of an adaptive sliding mode control (ASMC) algorithm [24] of single-phase microgrid system is proposed. It consists of three main renewable energy sources such as micro-hydro, wind and solar PV based generation.

The adaptive sliding mode control (ASMC) eliminates all possibilities of overshoot and undershoot problem in DC link voltage of the VSC which reduces the required size of DC link capacitor and BESS. The proposed control reduces the size required for DC link capacitor connected across the BESS. The proposed control never allows the increase of DC link voltage above the maximum float charge voltage that increases the life of the battery. The proposed sliding mode based control used for power balance is found highly suitable, stable and robust for such highly nonlinear microgrid system where the multiple parameters vary in a very large range. The ASMC algorithm provides a robust and adaptive control of system frequency and voltage with good dynamic and steady state response, which is the main requirement of a good standalone microgrid as reported by IEEE-PES Task Force on Microgrid control in [17]. The reported single-phase SEIG is investigated by many researchers for bio energy and small hydro driven systems but the benefits of this machine are not fully exploited for microgrid system (fearing the complications of nonlinear relationship in frequency, magnetizing reactance and speed of single phase SEIG). SEIGs have many advantages over other generators, like simple, brushless, low unit cost, low maintenance, high power/weight ratio, absence of DC excitation etc.

II. SYSTEM DESCRIPTION AND MODELLING:

2.1 System Configuration And Operating Principle:

The block diagram of proposed single-phase micro grid is depicted in Fig. 2.1. This micro grid consists of an unregulated micro-hydro turbine driven single-phase two winding SEIG (Self-Excited Induction Generator), a wind turbine driven PMBLDC (Permanent Magnet Brushless DC) generator, solar PV (Photovoltaic) array and a BESS. Conceptually, the single phase SEIG is only the AC generating source in this Micro grid, which directly caters the load whereas remaining two generating sources are connected to the load through a voltage source converter (VSC). It converts the DC power generated by PMBLDC generator and solar PV array into AC power when the power generated from

SEIG is less than the load. The solar PV-array, wind turbine driven PMBLDC generator and BESS are connected at the DC bus of the VSC.

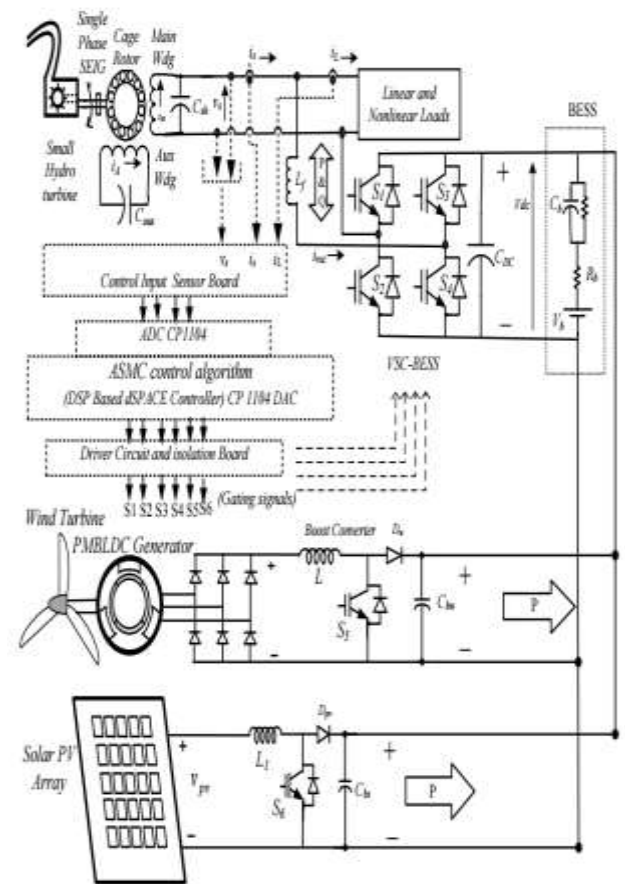


Fig. 2.1 System configuration of the single-phase micro grid

All these three energy sources supply only the real power to the system. They do not participate in any reactive power transaction with the system. When the total real power generated by the SEIG, PMBLDC generator and solar PV array is less than the load, then the BESS compensates the additional real power demand of the load. The VSC converts the DC power supplied by the BESS into the AC power to make it suitable for single-phase load connected at AC side of Micro grid. In the alternate case, the surplus energy is stored in the BESS to maintain the power balance. Under variable load conditions, single-phase SEIG and the load need adjustable harmonics and reactive power to maintain the micro grid AC voltage at rated value. The VSC is controlled using a DSP (Digital Signal Processor) to compensate this adjustable reactive power demand of the system. The VSC also compensates the real power need of the loads.

2.2 Control Algorithm For VSC-BESS Of Micro grid

An adaptive sliding mode control (ASMC) based algorithm is developed to estimate the reference source current and switching pattern for VSC of micro grid. The block diagram of proposed ASMC algorithm is shown in Fig. 2. It is well known that the SEIG system requires an adjustable reactive power under varying load conditions to maintain the PCC voltage at reference value.

The amplitude of terminal voltage of the single-phase

$$V_t = \sqrt{v_p^2 + v_q^2} \quad (1)$$

SEIG is estimated as,

where v_p and v_q are the in-phase and quadrature constituents of the micro grid AC voltage (or SEIG output voltage). The quadrature constituent of micro grid AC voltage is estimated and generated using frequency estimation and phase shifting (FEPS) block [18]. The micro grid AC voltage may be expressed as,

$$v_p = V_t \sin \omega t$$

$$v_q = V_t \cos \omega t \quad (2)$$

Where v_p is the instantaneous AC voltage, V_t is the amplitude and ω is the angular frequency of the micro grid AC voltage. The in-phase and quadrature unit templates of micro grid AC voltage are derived as,

$$u_q = \frac{v_q}{V_t} \quad \text{and} \quad u_p = \frac{v_p}{V_t} \quad (3)$$

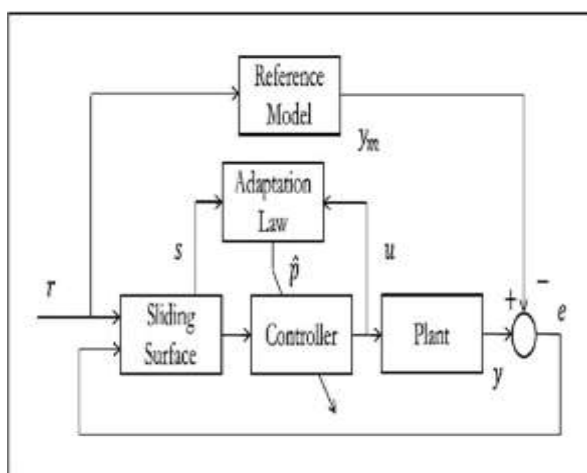


Fig2.2: Adaptive Sliding Mode Controller

An Adaptive control system automatically Compensates for variation in system dynamics. By adjusting the control characteristics so that the overall system performance remains the Same or rather maintained at optimum level.

The in-phase part of reference source current is responsible for frequency control of the system and power balance among SEIG, PMBLDC generator, solar PV-array, battery and the load. In proposed ASMC control algorithm, an adaptive filter is used to extract the amplitude of fundamental active and reactive power constituents of load current. The proposed control algorithm is a combination of two control loops. First loop controls its voltage by injecting an adjustable reactive power and other loop maintains active power balance among various energy elements in the micro grid.

III.FUZZY CONTROLLER :

The word Fuzzy means vagueness. Fuzziness occurs when the boundary of piece of information is not clear-cut. In 1965 Lotfi A. Zahed propounded the fuzzy set theory. Fuzzy set theory exhibits immense potential for effective solving of the uncertainty in the problem. Fuzzy set theory is an excellent mathematical tool to handle the uncertainty arising due to vagueness. Understanding human speech and recognizing handwritten characters are some common instances where fuzziness manifests.

Fuzzy set theory is an extension of classical set theory where elements have varying degrees of membership. Fuzzy logic uses the whole interval between 0 and 1 to describe human reasoning. In FLC the input variables are mapped by sets of membership functions and these are called as "FUZZY SETS". Fuzzy set comprises from a membership function which could be defines by parameters. The value between 0 and 1 reveals a degree of membership to the fuzzy set. The process of converting the crisp input to a fuzzy value is called as "fuzzification." The output of the Fuzzier module is interfaced with the rules. The basic operation of FLC is constructed from fuzzy control rules utilizing the values of fuzzy sets in general for the error and the change of error and control action. Basic fuzzy module is shown in fig.3

The results are combined to give a crisp output controlling the output variable and this process is called as "DEFUZZIFICATION."

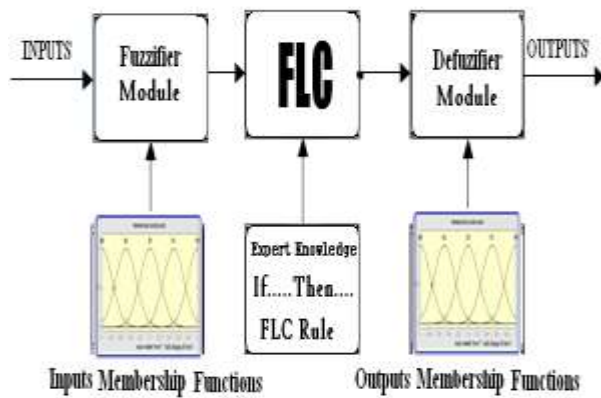


Fig 3: Block diagram of fuzzy logic

IV.SIMULATION DESIGN AND RESULTS:

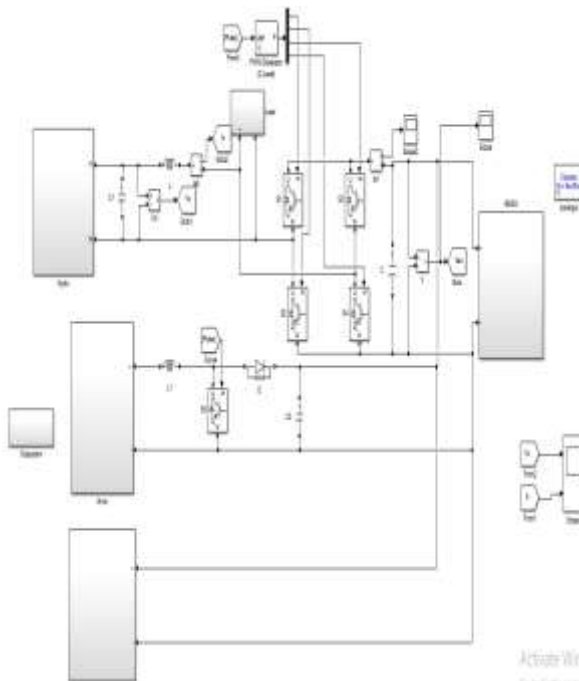


Fig4.1a) Simulation Design

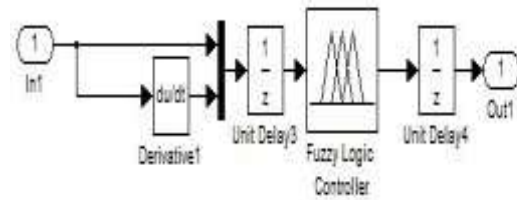


Fig4.1b) Fuzzy logic controller

Dynamic Performance Of Proposed Micro Grid:

i) Dynamic Performance of Proposed Microgrid at a Step Change in Solar Insolation Level

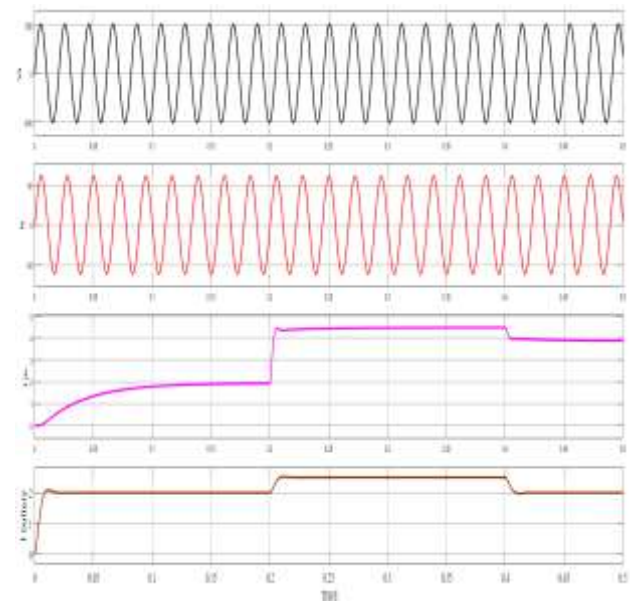


Fig 4.2(a) Dynamic Performance of the Vs, Is, Ipv and Ibattery, While the system is following a step increase and decrease in Insolation Level

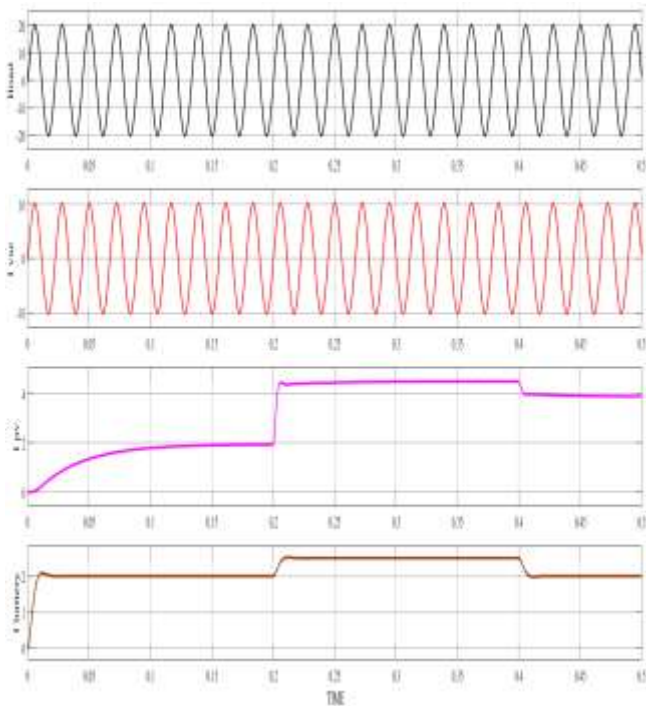


Fig 4.2(b) Dynamic Performance of the Iload,Ivsc, Ipv and Ibattery, While the system is following a step increase

The step increase in insolation level does not cause any disturbance or change in load current, as demonstrated in Fig. 6.9(a). The dynamic performance of the system voltage, SEIG current, solar PV-array current and battery current while the system is following a step decrease in insolation level, are demonstrated in . It is observed from test results shown in Fig 6.9(b)shows that the step decrease in insolation level causes a decrease the solar PV-array current with the same slope and it subsequently decreases the battery current but it does not disturb the system AC voltage, load current or system frequency. The battery current goes from charging to discharging mode in order to regain the power balance in the system as shown in Fig. Test results show that the system frequency and voltage are maintained constant during this dynamic condition.

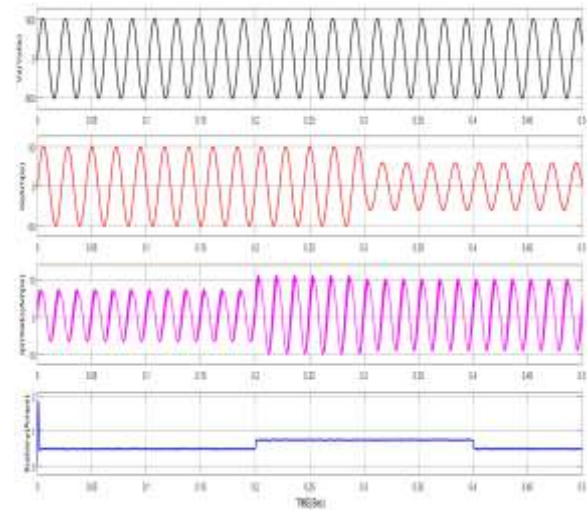
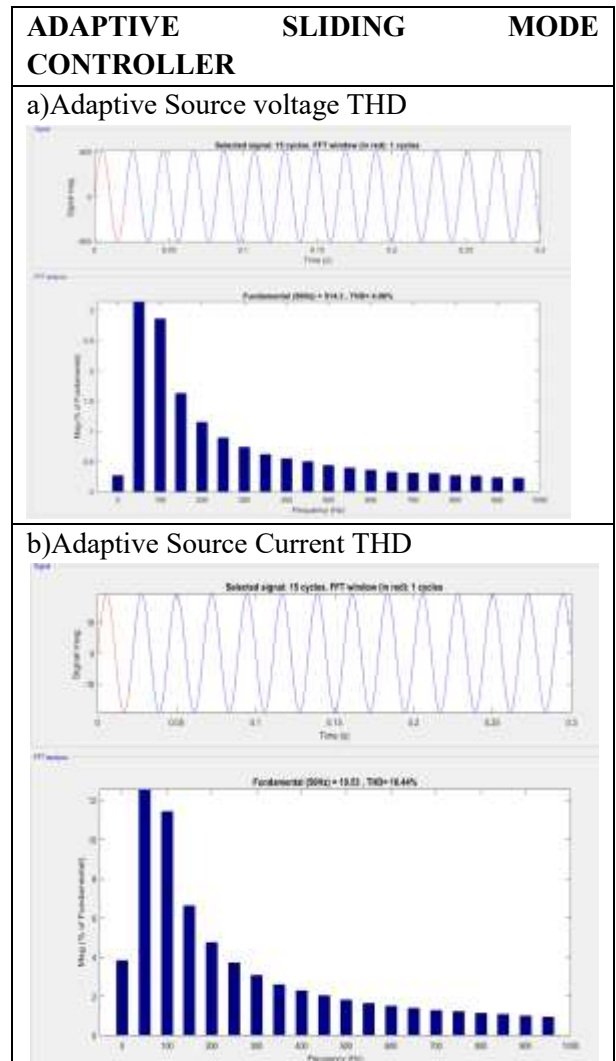


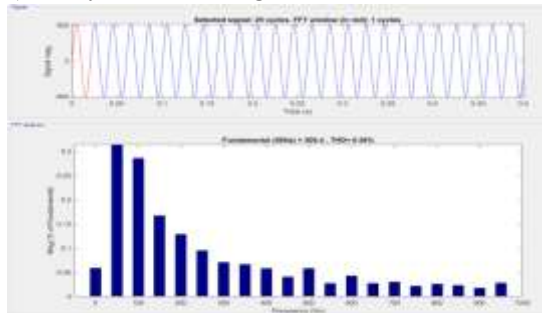
Fig 4.3 Dynamic Response of Vs,Is,Ipmbldc,Ibattery, while the system is following a step increase and decrease in wind speed

ii) Comparision Between Source Voltage and Load Current Total HarmonicDistortion(THD) Adaptive sliding mode Controller and Fuzzy Logic Controller:

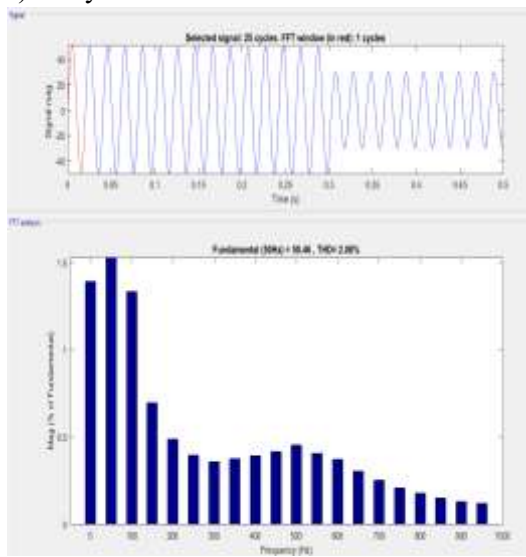


FUZZY LOGIC CONTROLLER

a) Fuzzy source voltage THD



b) Fuzzy source current THD



CONCLUSION

The adaptive sliding mode control algorithm for voltage and frequency control of standalone single-phase microgrid has been implemented. The proposed SEIG based standalone microgrid has integrated three main renewable sources including micro-hydro, solar PV, and wind energy. Test results have proven that the ASMC algorithm has been effective and has good control of the Microgrid voltage and frequency. The proposed control algorithm has also improved the power quality of the microgrid under linear and nonlinear loads and also ensures the optimum utilization of BESS and renewable energy sources. To reduce the harmonics of the system Fuzzy Logic Controller is introduced to the and the results are Compared with MATLAB/SIMULINK environment.

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