A Novel Approach of Enhancing the System Reliability in Wind - Hydro Microgrids for Remote Control Areas

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ABSTARCT: This proposed system deals with a renewable energy based micro grid (MG) for standalone operation. The places, where renewable energy sources such as wind, solar, hydro, etc., are in abundance; use them to generate electricity by developing wind-solar–hydro based MG. The main control unit of MG is voltage source inverter (VSI) in which an indirect current control is applied. This VSI is used for power quality improvements through harmonics suppression of nonlinear loads; voltage regulation during contingencies such as load unbalance; and reactive power compensation at point of common coupling according to the system requirement. The proposed method is not only enhancing the system performance it also having capability of increasing renewable source by integrating wind and solar powers. It is capable of providing power balance under various changes among the generation, storage, and demand units. For appropriate functioning of VSI, a reweighted zero attractor least mean square control algorithm is applied to generate pulse width modulation switching pulses for VSI. A model of MG is developed in MATLAB/Simulink environment to simulate its performance in normal and dynamic conditions at linear and nonlinear loads.

Keywords: wind–hydro, solar, VSI, power quality.

I.INTRODUCTION:

In developed regions of the world like USA and European countries, the energy is required to lead a comfortable lifestyle and for technological and industrial developments. The other aspect is also true that there are many countries in Africa and Asia, where some places are still deprived of electricity. People of such places have stagnant social development and minimal economic growth and they remain away from basic ancillary services like health, education, etc. In order to meet the increased demand of the world as well as to provide the basic ancillary services to far located places, the isolated microgrid (MG) [1]–[3] for rural electrification can be a noble option as compared to the normal grid. Such MGs can be ac and dc MGs having natural resources such as wind, solar, biomass, etc., and diesel generators (DGs) [4]–[7] to encourage the maximum use of renewable energy and economic utilization of fossil fuels. The worldwide energy consumption is reported in [8] for all conventional (fossil fuels, large hydro, nuclear, etc.) and renewable (wind, solar, small hydro, etc.) resources.

It is reported that up to 2020 the consumption of fossil fuels is to be reduced up to 76% and renewables are expected to grow up to 16% with a total supply of 17 208 MToe. This study shows that the renewables are taking over the fossil fuels slowly. The reasons to replace fossil-based energy with renewables, are the depletion of these sources, which has increased the fuel price [9] and their effect on environmental deformities such as greenhouse gases, global warming, and rise in health issues viz., impaired hearing, impairing visibility, dizziness, etc. [10], [11]. The research and development in power electronics have made applications of renewable energy to grow fast and smooth.

The electric power is provided to the remote places either by DG sets or available renewable resources such as wind, hydro, solar, etc. The DG sets impose cost on remote applications and lifestyle becomes expensive though the renewable resources are economic in generation but are very unreliable as their generations are season dependent. Therefore, the combinations of renewable resources can be a promising technology to attain the reliability [14]–[16]. In [14], photovoltaic systems are investigated with various control schemes. Such systems consist of dc–dc and dc–ac converters. Another combination of converters is called hybrid converters having switching between converters.

A hybrid MG is reported in [15] with wind and diesel resources. In such MG droop control is utilized for the frequency regulation of an ac bus. In [16], a renewable MG for energy management is reported having configuration with two converters, one is ac–dc and other is a dc–dc converter for smooth power flow. While in the proposed work, a single voltage source inverter (VSI) (dc–ac converter) as the control unit and one dc-dc converter is utilized for maximum power tracking (MPPT). In such system, the control complexity and cost of the system as well as maintenance are reduced. In standalone operations, voltage and frequency regulation and power management are important aspects as reported in [17]. In [18], Rezkallah et al. have reported detailed studies on ac MG configurations and control. Such MGs can serve isolated and interior places having green or hybrid resources. To protect battery overcharging dump loads are used. Perturb and Observe (P&O) and sliding mode controls are used for MPPT and pulse width modulation (PWM) pulse generation. Moreover, wind is very unreliable resource due to its variable and unpredictable nature.

To overcome this problem, battery storage [19] together with hydro power, which is available in all seasons, is used. Commonly the squirrel cage induction generator is used for hydro power generation due to its robustness and low maintenance but its efficiency is poor and frequency regulation is required. In this work, a synchronous reluctance generator (SyRG)-based hydro power generator delivers supply at rated frequency and voltage with the reactive power support using a capacitor bank. Such generators are without slip rings and rotor windings, therefore, the maintenance and the losses are reduced as a result, and its power efficiency is improved [20], [21]. The variable speed permanent magnet brushless dc generator (PMBLDCG) is used for wind power generation. It provides higher average power than the alternator as it has trapezoidal electromotive force and almost quasi-square shape currents. MPPT of wind power is achieved using a P&O technique.

II. LITERATURE SURVEY

2.1 Study and analysis of a small scale micro-grid using renewable energy resources

In Bangladesh utilization of renewable energy sources (RES) is very necessary to meet up the excessive energy demand. With available weather and technical data, a proper simulation tool can be helpful to utilize locally available RES in on-grid and off-grid areas. This paper presents modeling and the analysis of a small scale micro-grid system for community purpose in the rural and remote areas. A simulation tool 'mGrid_2014a' has been developed which can be used to analyze how RES can be effectively used to meet the community demand. Besides Solar and Wind, Biomass energy has been considered as a useful alternative source. Finally the model has been checked with locally available weather and RES data for the Saint Martin's Island, Bangladesh.

2.2 Microgrid modular design for tribal healthcare facilities: Kayenta health center PV system case study

This paper describes an experimental process and detailed information related to a 100KW PV system case study at the Kayenta Health Center, which is located in the Navajo Nation. Information about the solar irradiance on site, the PV system performance, the power quality at the facility, and observation of the related equipment is gathered. Experimental data validate the theoretical data available for the zone, the facility, the systems and the equipment. Detailed study of existing PV system at the Navajo Nation combined with modeling and simulation will lead to a good industrial pilot project from implementation and practical perspective of the microgrid in existing tribal health care facilities. A modified configuration of the existing power system is presented. The configuration provides guidance for redesign of existing healthcare facilities around the microgrid concept. Since the Kayenta Health Center is representative of the average healthcare facility in the Navajo Nation, this guidance will be useful for improvement power system of many tribal healthcare facilities. This in turn will improve the quality of the healthcare service and will benefit the living conditions of significant tribal population.

III.PROSED SYSTEM:

This MG functions for power balancing during wind fluctuations and load demand variations. A reweighted zero attractor least mean square (RZALMS) [23], [24] control approach is implemented in the MG VSI, which is the main control unit of the system. RZALMS accelerates the convergence rate and has lower mean square error than the standard LMS [23]. With the help of analytical demonstration, RZALMS is better on the standard LMS in both transient and steady-state performance for sparse and non-sparse systems. It offers harmonics reduction of nonlinear loads, voltage regulation at load variations, reactive power compensation based on system requirement. It also manages balanced power flow among various units, i.e., wind–hydro generators, the battery storage, and loads. The main contribution of the paper is as follows.

1. A single VSI control based MG is developed. Moreover, the wind power of PMBLDCG is converted into dc power using a diode rectifier. Therefore, this topology has reduced the overall cost of the system.
2. The PMBLDCG does not need sensors such as speed sensor, position sensor, and wind speed

sensor for MPPT control, thus further reducing the cost.

3. An RZALMS control approach is implemented in the MG VSI for fast responses during steady-state and dynamic conditions.
4. Generators used are maintenance free and having high efficiency.

Fig. 4.1 depicts the renewable-based MG comprising of hydro and wind sources. The hydro power is generated using SyRG, a constant power generator and this power is fed to the ac loads. The PMBLDCG is used to generate the electricity from wind power at variable speeds and a diode rectifier is used to convert it into dc power, which is fed to the boost converter for MPPT using the P&O control technique. This extracted power is delivered to the ac loads through a VSI and excess generated power is stored in the battery bank connected parallel to the VSI. This VSI is connected to the hydro power generator (SyRG) and loads at point of common coupling (PCC) through interfacing inductors (Lf). A capacitor bank is connected at SyRG terminals to support reactive power to MG for voltage buildup. The design data of the proposed MG are given in Appendix. To operate MG in satisfactory manner, it must provide good quality power as regulated sinusoidal voltage and frequency. This work presents MG performance with an RZALMS control approach to underpin a zero attractor for differentiating between zero taps and nonzero taps, as shown in Fig. 2. The parameters μ (step size), iLa (phase "a" load current), u pa (in-phase template), uqa (quadrature template), σ and ψ (small constants) are used in the control approach. Phase voltages are computed from line voltages as

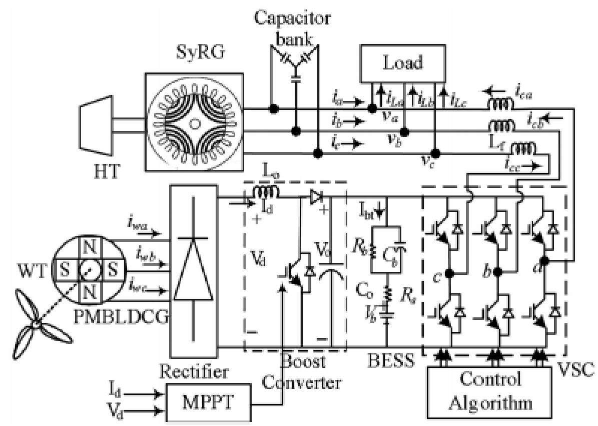


Fig.4.1 Wind-Hydro MG configuration

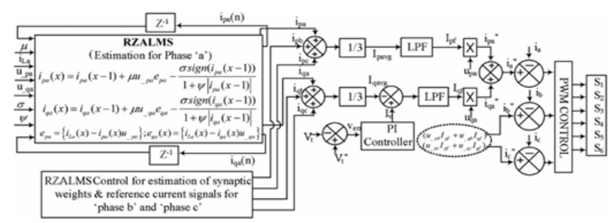


Fig. 4.2 MG Control approach.

$$v_{\_a} = 1/3\,(2v_{\_ab} + v_{\_bc}) \quad (1)$$

$$v_{\_b} = 1/3\,(-v_{\_ab} + v_{\_bc}) \quad (2)$$

$$v_{\_c} = 1/3\,(-v_{\_ab} - 2v_{\_bc})\,. \quad (3)$$

The terminal voltage Vt is derived from phase voltages as

$$V_{\_t} = \sqrt{(2\,(v_{\_a}^2 + v_{\_b}^2 + v_{\_c}^2)\,/3)}. \quad (4)$$

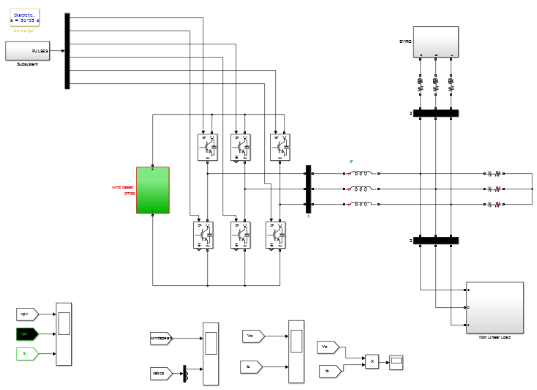
In-phase template of phase "a" voltage as

$$u_{\_pa} = v_{\_a}/V_{\_t}. \quad (5)$$

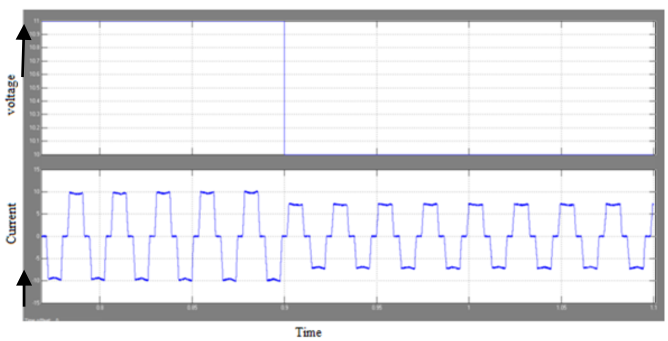
Similarly, other two in-phase templates for phase "b and c" (upb , upc) are also achieved. The quadrature voltage templates of three-phase voltages are as follows:

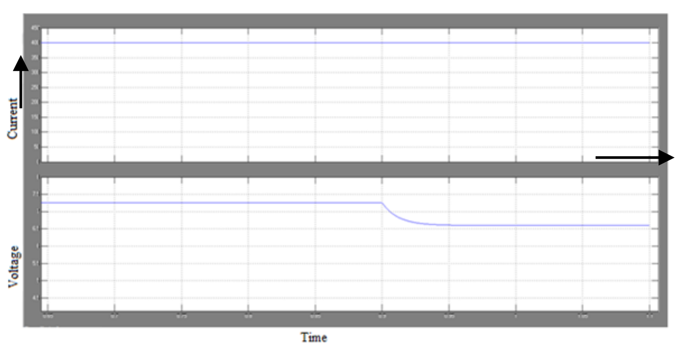
IV.SIMULATION RESULTS

Simulated results of MG are demonstrated in this section. Steady-state and dynamic responses of a renewable-based MG are shown and the behavior of intermediate signals of control approach at load unbalancing is depicted in detail. The wind MPPT using the P&O approach is also included. The MPPT of wind generation is achieved through applying a P&O approach. It is shown in Fig. 3 that at the wind speed variation, the PMBLDCG current of phase “a” is also reduced.



Proposed simlink model





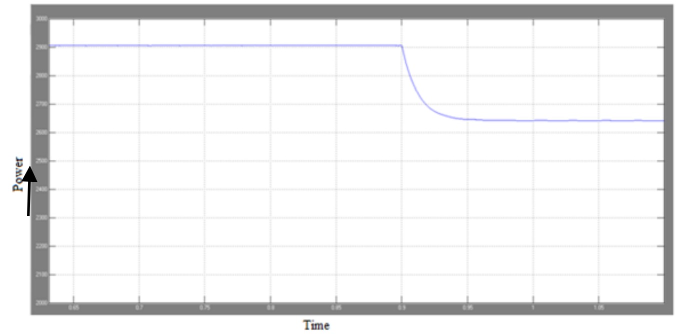
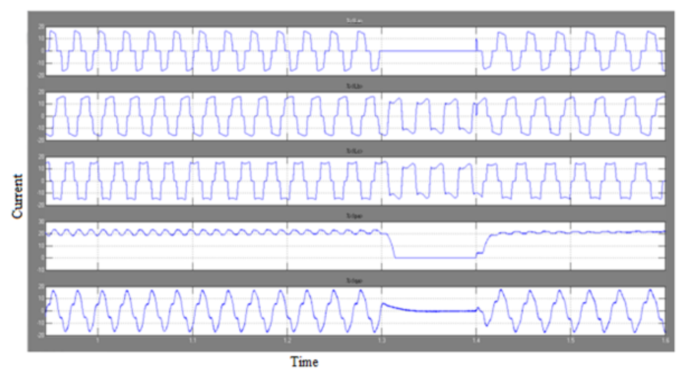
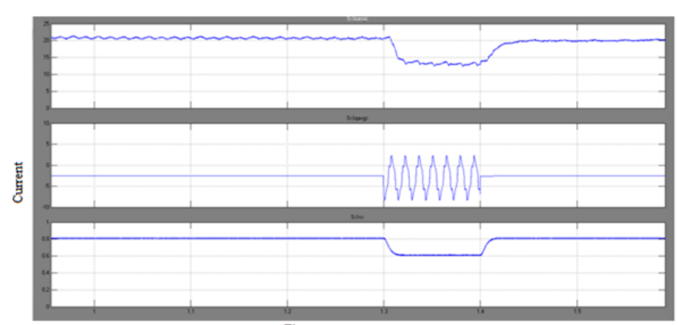


Fig. 5.1 P&O approach based maximum power tracking

The MPPT of wind generation is achieved through applying a P&O approach.It is shown in Fig.5.1 that at the wind speed variation,the PMBLDCG current of phase “a” is also reduced.

Therefore,the output of the dc-dc boost converter is alos reduced.The output voltage (vo)across the dc bus capcitor is fixed.The extracted power after MPPT is alos reduced with speed changes.





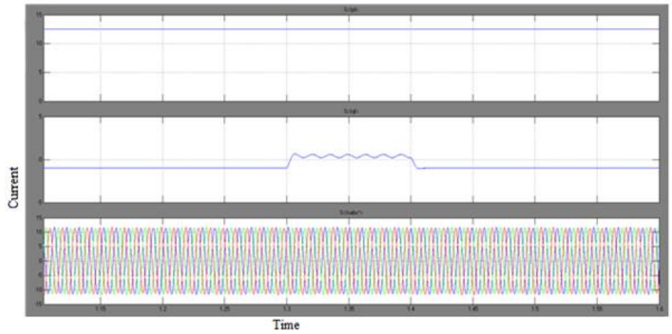


Fig. 5.2 Intermediate signals of RZALMS control algorithm at nonlinear load.

The performance of wind–hydro based MG depends on its control approach robustness. To demonstrate satisfactory response of the control approach, its various intermediate signals are depicted in Fig.5.2 at nonlinear loads. The load unbalance is created at t = 1.3 s, and the load on that phase is recovered at t = 1.4 s. It is seen that at load unbalance, the load current of phase "a" (iLa) becomes zero and other two phase currents iLb, iLc also change their shape. Simultaneously active and reactive load power components (ipa , iqa) also become zero. The equivalent active and reactive load current components (ipavg , iqavg) are also reduced as the total load demand is reduced due to the absence of load on phase "a." The current component coming from a PI controller (Iv) and the reactive source power current components (If q) also change with the load variation. The active source power current component (If p) is constant as prime mover power is fixed and reference source currents are sinusoidal and balanced. The intermediate signals of the control approach are changing rapidly to achieve the stead ystate condition within couple of cycles.

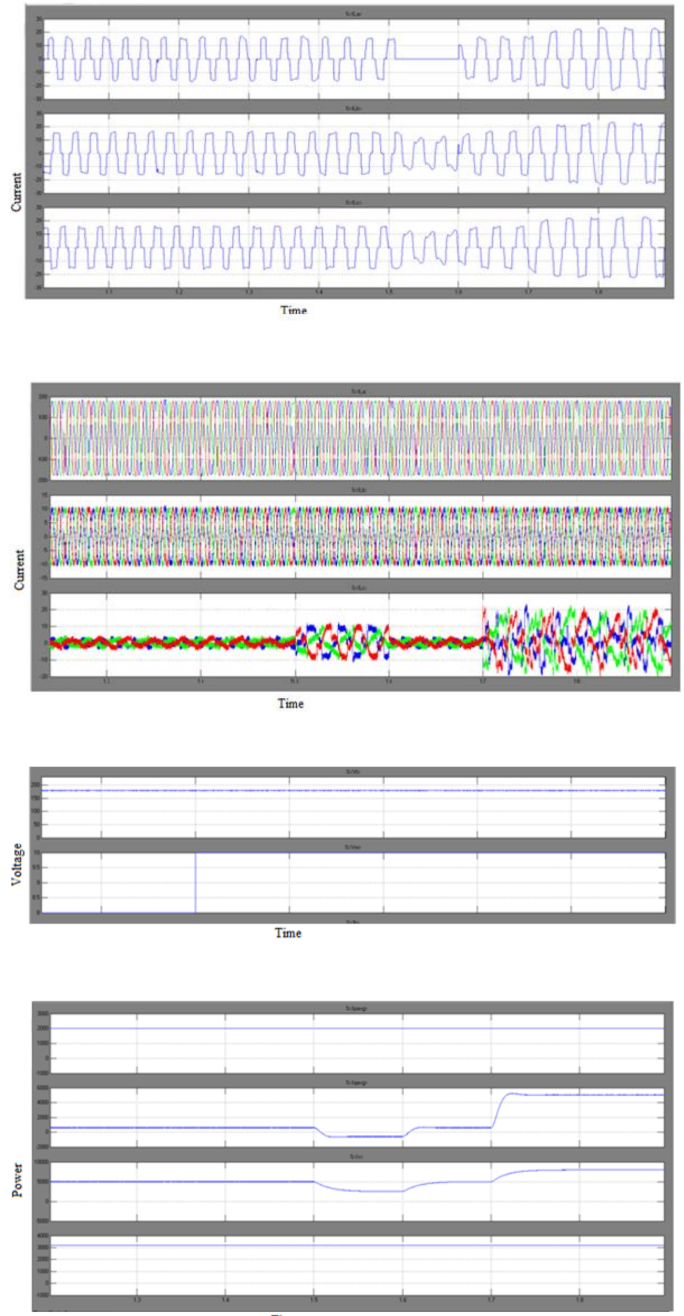
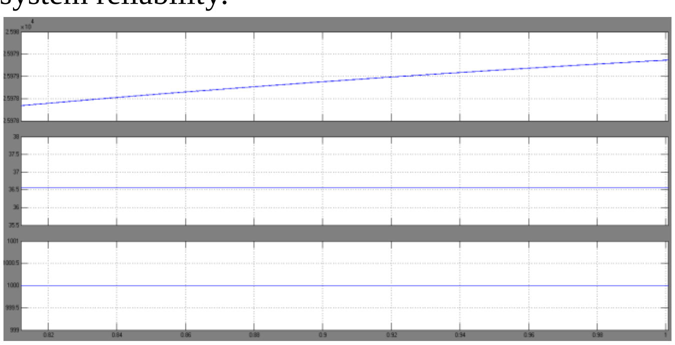


Fig. 5.3 Performance of MG under dynamic condition at nonlinear load

The dynamic performance of wind–hydro based MG under different scenarios is illustrated in Fig.5.3 at nonlinear load. At t = 1.4 s, the wind speed is increased, accordingly the wind power (Pwind) is also increased. The load demand (PL) and hydro generation (Phy) are fixed, therefore, increased renewable power is stored into the battery bank in terms of battery power (Pbt) and battery charging current (Ibt). During load unbalanced condition, when the load on phase "a" is unavailable at t = 1.5 s, the PCC voltages (vabc) are kept sinusoidal and constant and source currents (iabc) of MG also remain sinusoidal. The compensating currents of VSI (iCa, iCb,iCc) change their values to compensate reactive power demand to maintain balance in voltages and currents at PCC and to eliminate harmonics. The terminal voltage (Vt) is maintained constant at reference value (V ∗ t) throughout the operation. At t = 1.7 s, the load (i_{Labc} and P_L) is increased suddenly. With constant wind and hydro generation, the battery supports the system and discharges. This shows that during contingencies the MG provides satisfactory response.

Extension with solar power:

In this paper they propose only wind-hydro generating stations, generally both are inconstancy in nature so maintain the constant dc-link voltage is complicated because of variable wind speed so in this proposed method we integrate the solar power at common dc link at battery connection. Here we proposed solar-wind-hydro power generation and enhancing the system reliability.



Voltage, current and irradiance of solar power

From above waveforms our solar array is operating 1000w/m^2 irradiance to generate maximum power first screen of above mentioned waveform is representing voltage of the solar array second one is current and third one is irradiance.

In convention method authors are operating the system with different conditions like steady state and dynamic state to maintain the dc bus voltage is constant with different wind speeds like variable.

ADVANTAGES AND APPLICATIONS

Advantages

- Increase the system reliability
- Reduce the capital cost
- Reduce the size and space
- Reduce the extra inverter requirement

Applications

- Rural areas
- Remote control areas

V.CONCLUSION

In this paper we propose A renewable wind-solar–hydro based MG has been developed. The performance of MG has been demonstrated using RZALMS control approach to provide power quality solutions, i.e., harmonics suppression, reactive power compensation, load balancing, and voltage control. It has also managed the power balance in the MG during various states such as high wind power generation, load unbalancing, and peak load demand. Such MG provides energy independence in rural areas and contributes in reducing the fossil consumption and its bad impact on the environment. A single VSI has performed power quality improvement and power balancing. The PMBLDCG does not require speed sensor, position sensor, and wind speed sensor for MPPT control. The obtained results are clearly exposed that our proposed system is enhancing the system performance like efficiency and decrease the cost of the system. The proposed results are conducting in MATLAB/SIMULINK environments.

FUTURE SCOPE:

Generally any proposed method all the researchers concentrate in different areas like source side or load side or converter side or controlling side. In this proposed method we concentrate on source side integrate the solar system to existing system. In future we replace the conventional 3 phase VSI by MMC (Modular multilevel converters) and also have the one more possibility in case of controlling techniques we replace conventional or analog controllers like PI by digital controllers like FLC,ANN,ANFIS and wavelet controllers.

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