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MULTILEVEL INVERTER TOPOLOGY FOR INTEGRATED SMALL HYDRO-WIND GENERATION SYSTEM

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Abstract— Wind and hydro energy has many advantages, it does not pollute and it is an inexhaustible source. In this paper a Integrated model of small hydro and wind has been taken into consideration. This study presents a robust and cost-effective microgrid topology for integrating two commonly available wind and small-hydro renewable energy sources. Two generators has been used in this proposed topology one on hydro side and another one on wind side. pitch angle controller has been used for controlling the rotational speed of wind turbine furthermore Turbine and generator are coupled by the two mass drive train, Drive train transfers high aerodynamic torque at rotor to low speed shaft of generator through gearbox. The proposed system is integrated using a five level Multilevel inverter and a boost converter which are maintaining voltage and frequency, mitigating power quality problems and performing sensor maximum power point tracking by means of Incremental and conductance method respectively. separate batteries is also used in MLI at each phase for smooth supply to inverter .In this research work the investigation of small hydro and wind Integrated power system is done for obtaining the model characteristics in order to reduce stress on the transient stability. This research work is based on the model developed and simulated through Sim Power System simulation software in MATLAB.

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Keywords- Hydro energy generation system (HEGS); Wind energy generation system (WEGS); Multilevel inverter (MLI); Maximum power point tracking (MPPT); Photovoltaic (PV); Static compensator (STATCOM); PMSG.

Introduction

In this fast developing world nonconventional energy sources have drawn a lot of attention towards the generation of electricity. Various nonconventional energy sources like wind, biomass, tidal/wave, micro-hydro and PV are used because of their inexhaustible nature, capability of delivering clean power. Moreover in remote location utilization of electric energy from such non-conventional sources has been cheaper and easier as compared to the grid connection, which holds long transmission lines and associated losses. so when two or more than two power system of same nature are combined the resulting power system in known as integrated power system and combination of power systems of different nature is know as hybrid power system. At present fossil fuels contribute as the world's major energy sources. The non-renewable nature of fossil fuel and increasing energy demand have made it scarcer than before and therefore its price is skyrocketing. On the other hand renewable energy such as wind and solar is omnipresent free and abundant in nature. Since the renewable energy technologies are improving, the electricity cost produced by renewable form is certainly going to decrease significantly in near future [1-3]. Permanent magnet synchronous generator (PMSG) is considered as a very good option for the wind generator because of its high power density and hence small size, low maintenance [4]. A multilevel inverter used on wind side has various advantages , Multilevel inverter has a potential to generate output voltage waveform at a reduced switching frequency with less harmonic distortion if low voltage ratings using devices are used which make them a better choice for medium and high-voltage power applications[5-7].

Recently, pitch-adjusting variable-speed wind turbines have become the dominating type of installed wind turbines. Generally two controllers for the variable-speed wind turbines are used. Below rated value, in low wind speed, the speed controller can continuously adjust the rotor speed to maintain the tip speed ratio constant at the level which gives the maximum power coefficient, so the efficiency of the turbine will be significantly increased. Pitch angle regulation is necessary in conditions above the rated wind speed when the rotational speed is kept constant which can have a dramatic effect on the power output. The purpose of the pitch angle control might be expressed as follows [8-9]:

1) Optimizing the wind turbine power output. Below rated wind speed, the pitch setting should be at its optimum value to give maximum power.

2) Preventing the mechanical power input to beat the design limits. Above rated wind speed, pitch angle control provides an effective method of regulating the aerodynamic power and loads produced by the rotor.

3) Minimizing fatigue loads of the turbine mechanical component.

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Drive train model of two mass is used in the system as it transfers high aerodynamic torque at to shaft of generator through gearbox. In power systems simulations, the drive train model is usually represented by two masses [10-11], first mass stands for the wind turbine rotor (blades, hub and low-speed shaft), while the second mass stands for generator rotor (high speed shaft). The Incremental and Conductance (IC) method used in MPPT offers good performance under rapidly changing atmospheric conditions [12]. It is also capable of knowing whether the MPP has reached so does not oscillate like P&O method [13]. In other hand IC method is relatively more complex than P&O method. It requires four sensors to perform the computation thus is expensive and also requires more computational time which results in power loss [14-15]. Although IC is relatively faster than P&O it is still slow and inaccurate in faster variations of wind [16-17].

Renewable energy conversion system topology

The proposed standalone microgrid topology consisting of small-hydro and wind-energy conversion system is shown in Fig.1. A Integrated model has been developed in Matlab Simulink software of version R2016a. Hydro energy generation system (HEGS) has been placed on one side while Wind energy generation system placed another side.

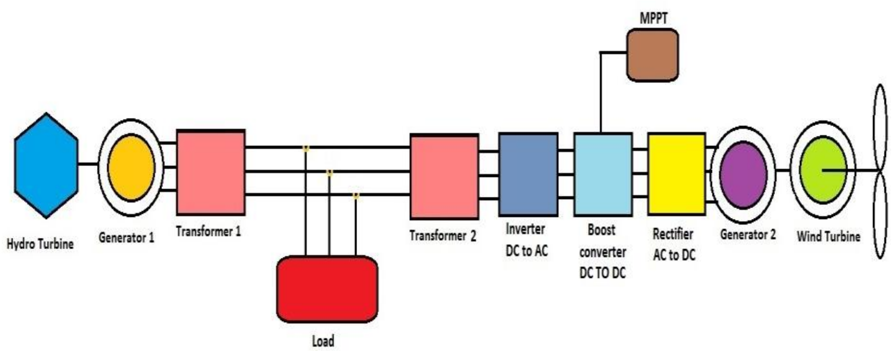

Fig.1. Proposed microgrid configuration

Potential Assessment-:

Wind Power System

The fundamental equation governing the mechanical power of the wind turbine is given by[18]-:

$$P_w = \frac{1}{2} C_p(\lambda, \beta) \rho A V^3$$

where ρ is air density (kg/m3), Cp is power coefficient, A is intercepting area of the rotor blades (m2), V is average wind speed (m/s), λ is tip speed ratio. The theoretical maximum value of the power coefficient Cp is 0.593, also known as Betz's coefficient.

The Tip Speed Ratio (TSR) for wind turbine is defined as the ratio of rotational speed of the tip of a blade to the wind velocity Mathematically[18]-:

$$\lambda = \frac{R\omega}{V}$$

where R is radius of turbine (m), ω is angular speed (rad/s), V is average wind speed (m/s).

The energy generated by wind can be obtained by [18]-:

$$Q_w = P \times (Time)[\text{kWh}]$$

Hydro Power System

The hydro potential of the system is given by [18]-:

$$Q_{site} = K\left[\frac{A_{site}}{A_{gauge}}\right]Q_{gauge}$$

where A_{site} is catchment area of power plant (m2), A_{gauge} is catchment area of gauge (m2), Q_{site} is discharge at site (m3/s), Q_{gauge} is discharge at gauge (m3/s), and K is scaling constant or function.

The mechanical power generated by the turbine is given by [18]-:

$$P = \eta_{total}\rho g Q H$$

where P is mechanical power output produced at the turbine, ηtotal hydraulic efficiency of the turbine, ρ is density of water (1000 kg/m3), g is acceleration due to gravity (9.81 m/s2), and H is effective pressure head (m).

MATLAB Simulation

Following two cases has been developed for comparative analysis. Case 1 - Fig.2 is without statcom and Case 2 - Fig.3 is with statcom.

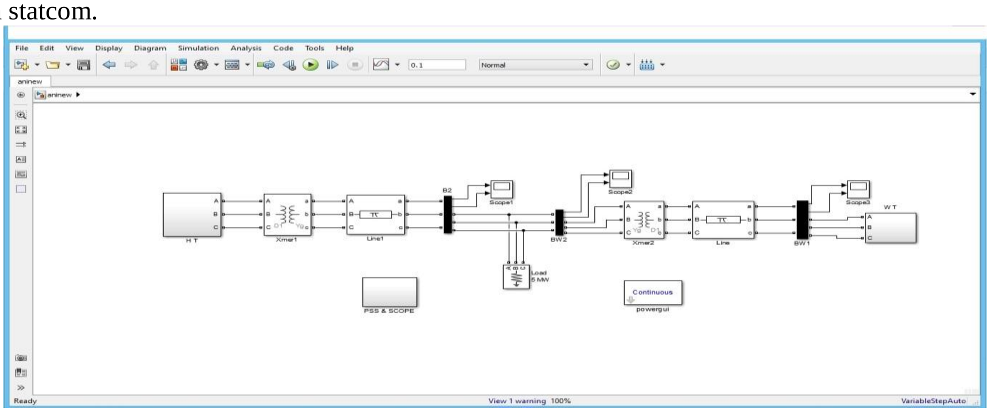

Fig.2. Integrated small hydro-wind generation system

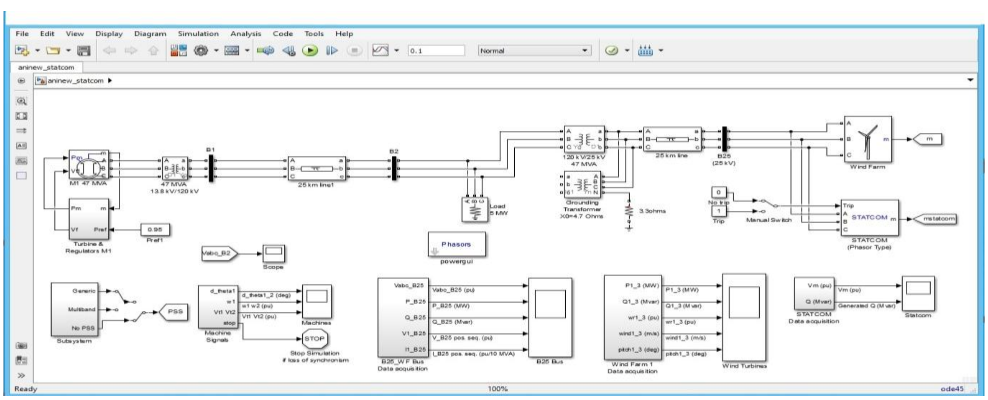

Fig.3. Integrated small hydro-wind generation system with Statcom

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Hydro energy generation system (HEGS) is consist of Turbine which is connected to synchronous machine which is further connected to transformer 1 and line parameters. Step up Transformer of 13.8kv/120kv and line parameter of distance 25km is connected to the system, which further connects the load.

Wind energy generation system (WEGS) is consist of more devices as compared to HEGS. In one case Wind turbine system has been developed in Simulink software and in another case Wind turbine (mask) has been used form Simulink library as wind turbine. In order to have continuous mechanical energy a pitch angle controller is connected. The pitch angle control method is a basic approach for controlling the rotational speed of wind turbine. Turbine and generator has been coupled by the two mass drive train, because Drive train transfers high aerodynamic torque at rotor to low speed shaft of generator through gearbox. Generator further connected to the rectifier (ac to dc conversion) which is further connected to chopper (boost chopper – dc to dc conversion). The Chopper is receiving signals from MPPT for specified signals. Incremental and conductance (I&C) method has preferred in MPPT over perturb and observe method (P&O), I&C method fast and less time taking and is better for fast varying system like Wind it consist of sensor while p&o is sensorless method which is lengthy and time taking. Now Chopper is connected to five level multilevel inverter (dc to ac conversion), output of MLI is step-up by transformer (9mw/25mw) and is further connected line parameter of distance 25 km. Finally this system has been connected to another step-up transformer of 25mw/120mw which is equivalent to HEGS. In case-2 Shunt static compensator has been used to compensate voltage. We can observe from the diagram WEGS is more complex than HEGS as more number of components has been connected to wind side for proper output.

Result and Discussion

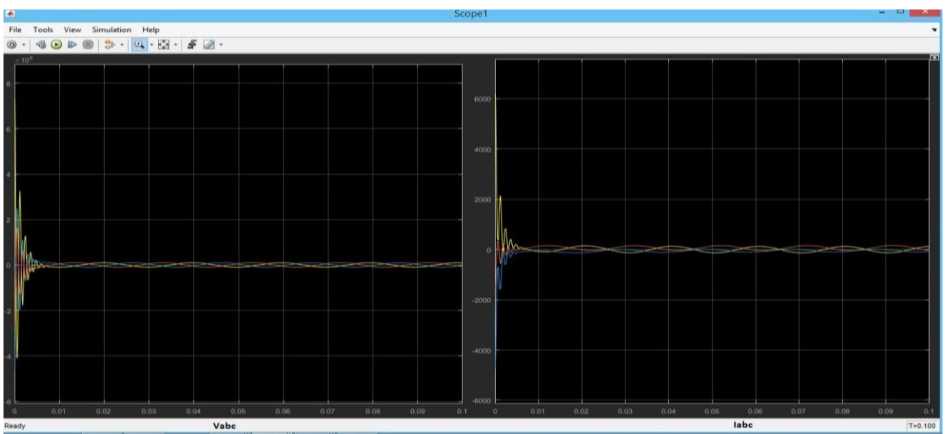

Fig.4.HT side output of Vabc and Iabc (case 1)

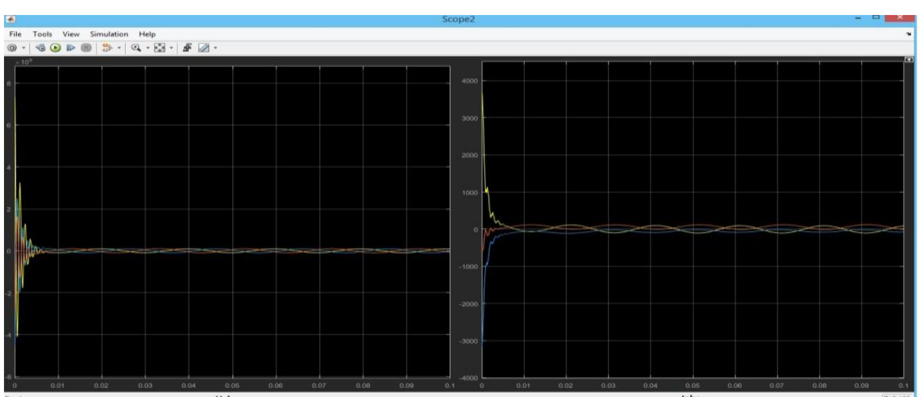

Fig.5.WT side output of Vabc and Iabc (case 1)

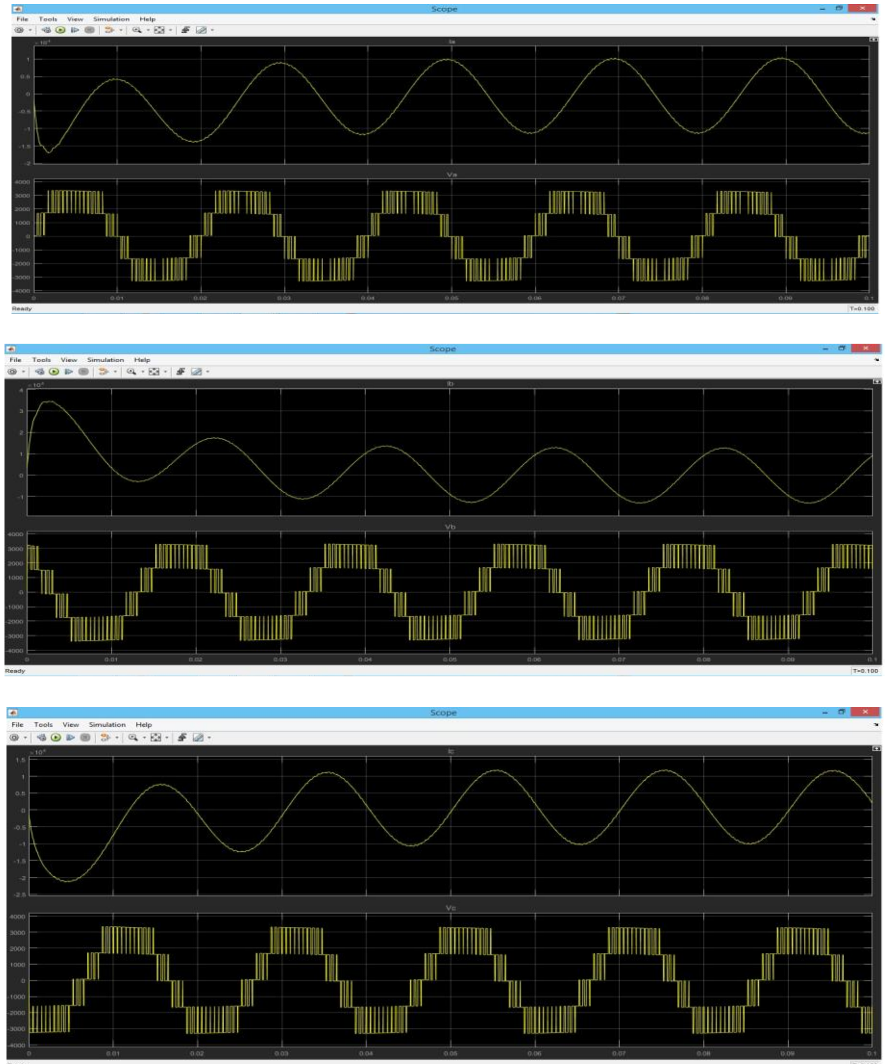

Fig.6. Inverter output phase A , phase B , and Phase C respectively(case 1)

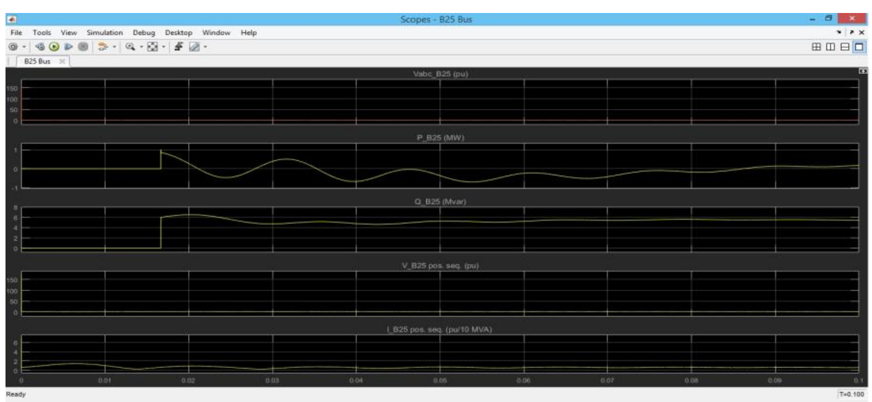

Fig.7. WT side output of V_{abc} , P ,Q, V_{pos_seq} , $I_{pos\_seq.}$ respectively (case 2)

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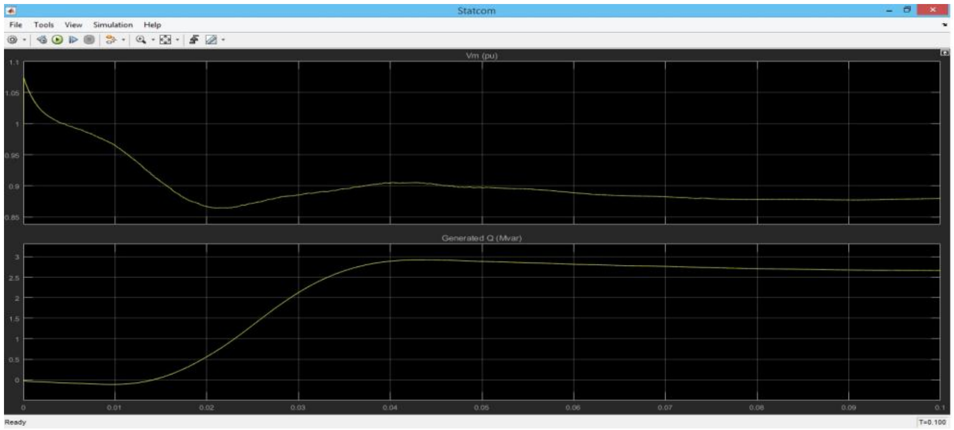

Fig.8. Statcom output (case 2)

The proposed system has been tested for operational feasibility under various conditions, that is steady state or under any disturbance. The control algorithms for voltage–frequency control, power quality mitigation and MPPT with sensor in WECS are also tested under different conditions. From the outputs we can observe that, in case 1 V_{abc} and I_{abc} of the both Fig.4.HT side and Fig.5.WT side attained stability after sometime system started. Switching has been done in MLI by Sinusoidal pulse width modulation (SPWM) technique and generated output of each phase is shown in Fig.6. in case 2 various output is shown in Fig.7. in which V_{abc} has been shown at stable condition as well as active and reactive power became stable after sometime.

Conclusion and Future Scope

In this research work the analysis of system stability of the small hydroelectric and wind power integrated power system have been done in order to achieve continuous power. it eliminates the transients and fluctuation and increase the desired electrical energy output to the consumers in the rural areas and weak and isolated parts of the grids. The structure and control of the proposed micro-grid have only renewable energy sources along with batteries at MLI. The proposed system is a good option for the locations where national grid is not present. The proposed topology and generators have low cost, robust and maintenance free. Moreover, the performance of the controller has been proven satisfactory under various disturbances and steady-state operation. The experimental results have verified the stability and robustness of topology and the controller under various situations.
In future investigation with more than one hydroelectric or wind power system can be done. There is also possibility of developing renewable integrated model with non-renewable one. As investigation was done without taking in account some of power system parameters, so in future investigation on transient stability can be done considering whole parameter and it can be evaluated with others parameters too.

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Appendix

Simulation model-:

Wind turbine: 1.5 MW (case 1) and 2 x 1.5=3 MW (case-2), rated wind speed = 14 m/s in case 1 and 9m/sec in case 2, pitch angle (fixed) = 0° in both cases.