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DESIGN AND CONTROL OF MICRO-GRID FED BY RENEWABLE ENERGY SOURCES

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Abstract - This project presents a control of a Micro-Grid at an isolated location fed from wind and solar based hybrid energy sources. The machine used for wind energy conversion is doubly fed induction generator (DFIG) and a battery bank is connected to a common DC bus of them. A solar photovoltaic (PV) array is used to convert solar power, which is evacuated at the common DC bus of DFIG using a DC-DC boost converter in a cost effective way. The voltage and frequency are controlled through an indirect vector control of the line side converter, which is incorporated with droop characteristics. It alters the frequency set point based on the energy level of the battery, which slows down over charging or discharging of the battery. The system is also able to work when wind power source is unavailable. Both wind and solar energy blocks, have maximum power point tracking (MPPT) in their control algorithm. The system is designed for complete automatic operation taking consideration of all the practical conditions. The system is also provided with a provision of external power support for the battery charging without any additional requirement. A simulation model of system is developed in MATLAB environment and simulation results are presented for various conditions e.g. un availability of wind or solar energies, unbalanced and nonlinear loads, low state of charge of the battery.

Keywords: DFIG, Vector Control, Wind Energy; Power Quality, Solar PV Energy, Micro-grid, Battery Energy Storage System, Renewable Energy System.

1. INTRODUCTION

There are numerous remote areas on the planet, which don't approach power. There are additionally numerous spots, which are associated with the network, be that as it may, they don't get power for up to 10-12 hours in the day and because of it, financial exercises of occupants endure. A large number of such places are wealthy in sustainable power source (RE) sources, for example, wind, sun based and bio-mass. An independent age framework using locally accessible RE sources, can enormously lessen the reliance on the network control, which is dominatingly fossil power. Wind and sunlight based vitality sources, are more most loved than bio-mass based framework as last is powerless to production network issue. Notwithstanding, wind and sun based energies experience the ill effects of abnormal state of intensity inconstancy, low limit use factor joined with flighty nature. Because of these variables, firm power can't be ensured for self-ruling framework. While the battery vitality stockpiling (BES) can be useful of bringing down power change and expanding consistency, usage factor can be expanded by working every vitality source at ideal working point. The ideal working point likewise called as most extreme power point following (MPPT), requires guideline of the working purpose of wind vitality generator and sunlight based PV (Photovoltaic) cluster in term of speed and voltage to separate greatest electrical vitality from info asset. The MPPT can be accomplished by power hardware (PE) based control

2. SYSTEM COMPONENTS DESCRIPTION

A solitary line chart of the proposed sustainable power source age framework (REGS) nourished miniaturized scale network is appeared in Fig. 1. The equivalent has been intended for area having greatest power request and normal power request of 15 kW and 5 kW, separately. The evaluated limit of both breeze and sun oriented vitality hinder in REGS, is taken as 15 kW. The limit usage factor of 20% is considered for both vitality squares, which is sufficient to give entire day vitality prerequisite of the villa.

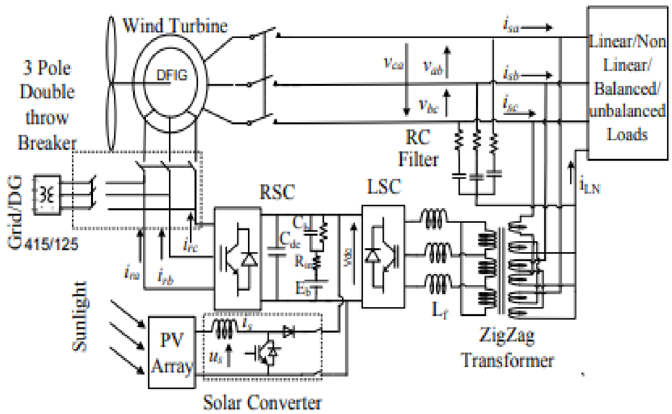

Fig. 1 Schematic of isolated micro-grid network fed by renewable energy source using battery storage

A. Wind Turbine and Gear

The breeze turbine catches the motor vitality of the breeze and gives driving torque to DFIG. The estimation of caught mechanical power is given as,

$$P_{wind} = \frac{\pi}{8} dD^2 v^3_{wind}$$

B.DFIG

An outside power stream in DFIG, is through both stator and rotor. Ignoring misfortunes, at most extreme breeze speed, the ostensible influence of DFIG (Pe) is identified with appraised air hole influence (Pag) as,

Pe= Pag/(1+|spmax |))

C. Transformer

The crisscross transformer should meet the joined kVA necessity of burden just as associated channels. Appropriately, a 20 kVA transformer is picked, which is adequate to exchange appraised control alongside meeting responsive power prerequisite of the associated loads and channels at pinnacle request

D.Battery Sizing

The most extreme working slip of machine is 0.3. The DFIG speed comparing to this slip is 110 rad/s. At this slip, the line voltage of rotor Vrmax become 125 V (415×0.3). The required DC transport voltage (Vdc) for PWM control is as

$$V_{dc} > \{2(\sqrt{2/3})V_L\} m_i$$

E. Sun powered PV System

The essential component of a sun oriented PV framework is the sun based cell, which depends on crafted by Rey-Boué et al [15]. The sun based boards are designed with the end goal that the open circuit voltage of the sun based string stays not exactly the most reduced downstream voltage of sun based converter or DC transport voltage, Vdc. The phone numbers (Nc) in a string, is an element of its DC voltage and cell open circuit voltage Vocc as,

Nc=Vdcm/Vocc

F.High Pass Filter

To lessen voltage ripple,a high pass channel is utilized at stator terminal , which time steady ought to be not exactly key recurrence for example 20 ms. In addition, it ought to be tuned a large portion of the exchanging recurrence. The exchanging recurrence is 10 kHz and as needs be the channel to be intended for 5 kHz. In the present plan, an arrangement RC channel comprising of 5 Ω obstruction and 15 μF capacitance, is associated at the stator terminals of DFIG. The channel gives under 5.43 Ω impedance for symphonious voltage having in excess of 5 kHz recurrence

3. CONTROL ALGORITHM

As appeared in Fig.1, REGS comprises of three converters, which control depictions, are given as pursues

A.Control of Solar Converter

A sun powered converter, which is a lift type DC-DC converter used to empty sun based power with inserted S-MPPT rationale. It depends on steady conductance strategy [16]. The S-MPPT through savvy exchanging manages us so as the nearby planetary group works at MPP. The stream outline of the MPPT calculation is appeared in Fig.3.

B.Control of LSC

Since the coastal breeze turbine produces control just for 60-70% of the time, the framework ought to be intended to work when no wind control is accessible. As appeared in the control graph in Fig. 4, i*qs comprises of two parts. The first segment, iqs1 compares to the power segment of DFIG current, when wind turbine is in task. The second component i corresponds to the power segment drawn

TABLE FOR TECHNICAL DETAILS OF SOLAR BLOCK

Open Circuit Voltage of PV cell, V_{occ}	0.64 V
Open circuit voltage of a module (V_{oc})	23.04 V
MPP voltage of PV cell, V_{mpc}	0.5223 V
MPP Voltage of module(V_{mp})	18.83 V
Short Circuit current of module(I_{sc})	8.69 A
MPP current of module (I_{mp})	8.04 A
Module Power Rating	151 Wp
μIsc	0.04 %/ ^{o}C
μVoc	-0.36%/ ^{o}C
PV Modules in the solar block	11 strings each having 9 PV modules.
String open circuit voltage, u_{soc}	207.36 V
Capacity of Solar PV System	15 kWp

1).Frequency Set point f*s Computation: The stator recurrence is constrained by the LSC. Despite the fact that the framework needs to produce appraised recurrence, a hang trademark has been fused which gives recurrence set point as,

$$\omega_e^* = 2 \times \pi \times [50 + \{2 \times (V_{dc} - 240)/(V_{dcmax} - V_{dcmin})\}]$$

2) i*ds Computation: i*ds is the charging segment of stator current required at burden terminal and is figured as,

$$i^*_{ds(k)} = i_{ds(k-1)} + K_{pv}(v_{err(k)} - v_{err(k-1)}) + K_{iv} v_{err(k)}\, dt$$

where $V_{err(k)}$ is the voltage error

$$v_{err(k)} = V^*_{Lm} - V_{Lm(k)}$$

3) i*qs Computation: As talked about, i*qs is isolated into two sub-segments as,

i*qs = i*qs1 +i*qs2

i^*_{qs1} is the quadrature component of the generator along the stator field and is computed as,

$$i^*_{qs1(k)} = -L_m * i_{qr(k)} / L_s \quad (15)$$

i^*_{qs2} is the required quadrature of stator current when DFIG is not connected to the LSC(or load) on account of low wind speed or fault. It is the evaluated as follows,

$$i^*_{qs2(k)} = i_{qs2(k-1)} + K_{p\omega e}(\omega_{eerr(k)} - \omega_{eerr(k-1)}) + K_{i\omega e}\omega_{eerr(k)}\, dt \quad (16)$$

C. Control of RSC

RSC manages the speed of turbine with the goal that the framework works at MPP independent of shifting breeze conditions. It likewise gives charging capacity to the generator. The control reasoning as appeared in Fig. 5, incorporates control calculation for

1)i*dr Computation: idr is identified with charging intensity of machine in field arranged vector control(FOVC). The no heap charging power is to be provided through RSC and the relating idr is as,

$$i^*_{dr} = I_{ms}0 = V^*_{Lm} / (\sqrt{3}X)$$

2) i*qr Computation: In FOVC at steady stator transition , the quadrature part of the rotor current, i*qr is relative to the torque ds

$$i^*_{qr(k)} = i_{qr(k-1)} + K_{p\omega r}(\omega_{rerr(k)} - \omega_{err(k-1)}) + K_{i\omega r}\omega_{rerr(k)}\,dt$$

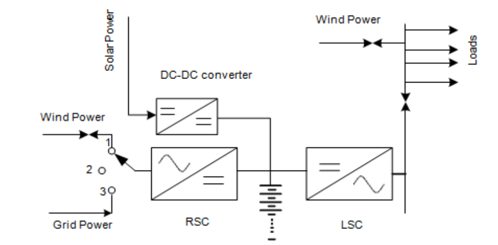

Fig. 2 Energy flow diagram of isolated micro-grid network fed by renewable energy source using battery storage

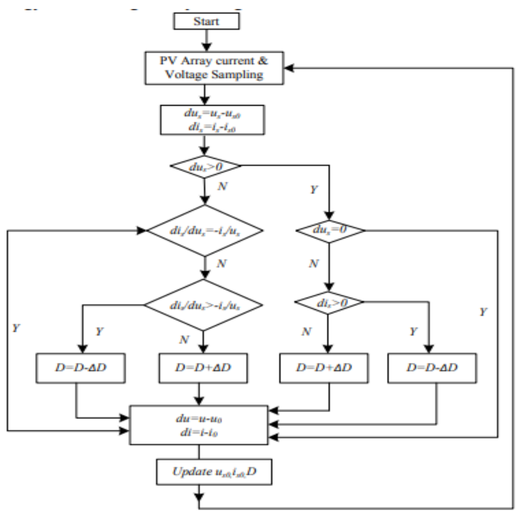

Fig. 3 Flow-diagram of solar MPPT algorithm

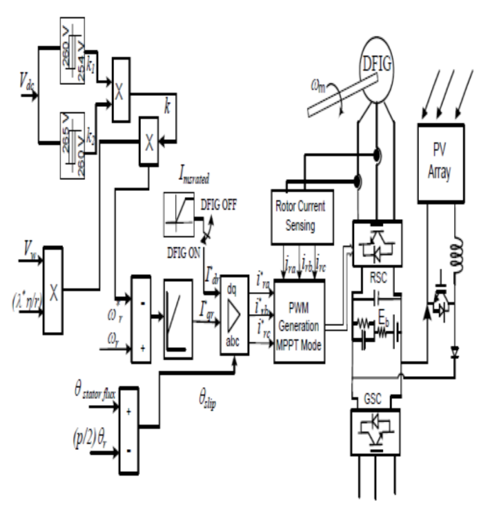

Fig. 5 Control diagram of RSC for REGS fed micro-grid

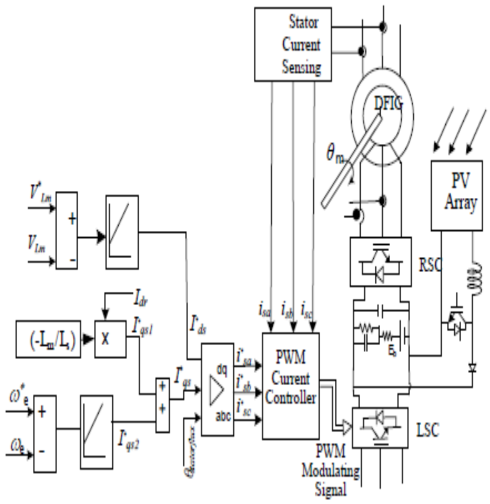

Fig. 4 Control diagram of LSC for REGS energy fed micro-grid

4. Results and Discussion

The Simulink model of miniaturized scale lattice sustained by REGS is created in Matlab. The sun oriented boards and wind turbine are demonstrated utilizing their capacities. Fig. 7 demonstrates the execution of the framework when the breeze generator is removed in a from the framework. Fig. 8 demonstrates the execution of the framework when sun oriented PV framework is removed in and taken from the framework. Both the above situations likewise examine the MPPT activity through RSC and sun powered converter. Fig. 9 indicates outcomes at loss of burden and Fig. 10 at lopsided nonlinear burden. Fig. 11 demonstrates a situation when put away vitality and created control are low and outside charging necessity through RSC is initiated. Fig. 12 demonstrates situation when DC transport voltage is running at high charging force.

A. Execution of System at Constant Load and Cut-in and Cut-out of Wind Power

As appeared in Fig. 7, the framework is begun with 10 kW and 6 kVAR burden without wind or sunlight based vitality sources. At t=2.25 s, the breeze generator at wind speed of 7 m/s, is taken in administration. Subsequently, a flashing variance in the framework voltage is watched. At t=6.0 s, the breeze speed of turbine is expanded from 7 m/s to 8 m/s pursued by decrease of the breeze speed to its unique incentive at t=10.0 s. The rotor control activity, keeps up the ideal rotational speed according to the W-MPPT calculation. At t=14 s, the breeze generator is removed from administration.

Amid cut-in and pattern of wind generator, fleeting, the voltage flood is watched. The length and extent of the voltage flood, are inside an IEEE 1547 standard.

B. Execution of System at Constant Load and Cut-in and Cut-out of Solar Power

The framework is begun with a 10 kW and 6 kVAR burden without wind or sun oriented vitality. As appeared in Fig. 8, at t=2.25 s, nearby planetary group is taken into the administration at radiation of 800 W/m2. At t=4 s, the sun powered radiation is raised to 900 W/m2 and again it is decreased to 800 W/m2 at t=6 s. The sun powered converter changes the sun oriented PV voltage and works at S-MPPT. At t=7 s, the nearby planetary group is removed from administration. No noteworthy variety of framework voltage is seen at any progress point.

C. Execution of System at Unbalanced Nonlinear Load

The execution of the framework at uneven nonlinear is appeared in Fig. 9. A miniaturized scale lattice ought to be appropriate to give necessity of lopsided nonlinear burden. A most dire outcome imaginable is taken when there are no producing sources. The associated burden comprises of 2 kW direct burden and 8 kW nonlinear burden. At t=3.25 s, the heap of a-stage is disengaged from the system pursued by b-stage load at t=3.46 s. It is seen from the outcomes that the framework can give quality capacity to its client if there should be an occurrence of uneven just as nonlinear burden.

D. Execution of System at Loss of Load

The execution of the smaller scale lattice for loss of burden, is appeared in Fig. 10. A 10 kW and 6 kVAR burden, is associated at the terminals before beginning of reenactment. Neither breeze nor sun oriented power, is accessible and the heap is encouraged by the battery. At t=2 s, the framework load is disengaged. It is discovered that the framework voltage and recurrence stay consistent of the system

E. Framework Running without Generating Source and Battery Charged from the Grid

Fig. 11 demonstrates the situation when there are no creating sources nourishing to the system joined with low battery. Outside charging is required to continue the heap necessity. Charging circuit is empowered according to the rationale graph of Fig. 6. At t=4 s, wind age is removed from administration and due to bring down battery voltage, the charging circuit is started. Subsequently outside power is infused through the RSC to provide food load necessity notwithstanding charging the batteries.

F. Execution of System amid High Generation and Over-voltage Scenario of DC transport

Execution of framework at high net age and over-voltage situation of DC transport, is appeared in Fig. 12. To make the impact noticeable, the AH of the battery is diminished by 1/200 times. The breeze speed and sun based irradiance, are kept 9 m/s and 700 W/m2 individually. It is seen from the bend, that once the Vdc achieves 260 V, RSC control decreases the DFIG speed set point to 85% of the MPPT set point. It is seen from Fig. 12 that charging power, Pc is decreased and the voltage rise is diminished

5.CONCLUSION

The proposed miniaturized scale network framework bolstered from REGS has been discovered appropriate for meeting load prerequisite of a remote separated area including couple of family units. REGS involves wind and sun based vitality squares, which are intended to extricate the greatest power from the sustainable power sources and in the meantime, it gives quality capacity to the shoppers. The framework has been intended for complete robotized activity. This work additionally shows the measuring of the significant segments. The execution of the framework has been introduced for change in information conditions for various kind of burden profiles. Under every one of the conditions, the power quality at the heap terminals, stays inside worthy point of confinement. The adequacy of the framework is additionally given test results with model in the research facility. The framework has likewise conceived the outside battery charging by using the rotor side converter and its sensors for accomplishing rectifier task at solidarity control factor

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