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SPV Array Fed Water Pumping Machine Using A Switched Reluctance Motor (SRM) Drive

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Abstract: This paper gives a solar photovoltaic (SPV) array fed water pumping machine using a switched reluctance motor drive. The virtual commutation of SRM power at critical frequency gives decreased switching losses in a mid-factor converter and drastically Increases the efficiency of proposed system. The velocity of SRM is controlled by using numerous the dc-bus voltage of the mid-point converter. A DC-DC Boost converter running in continuous conduction mode (CCM) is used for dc-bus voltage manipulate. The CCM operation of inductors helps to reduce the ringing impact and decreases the losses of DC-DC converter. Present day and voltage stresses on devices which consist of switching pressure of Boost converter are also reduced in CCM. The Boost converter facilitates The non-stop and clean input/output currents to SRM force with boundless place for maximum power factor tracking (MPPT) operation. The adjustment in step length of an Incremental conductance (InC) MPPT set of policies helps the smooth starting of SRM force. The proposed system, subjected to dynamically atmospheric situations is designed, Modeled and simulated the usage of Matlab/simulink environment. A prototype of proposed configuration is likewise superior and its performance is established with test results for manipulate of pace over various insolation ranges.

Keywords: Non-stop conduction mode (CCM), Boost converter, Incremental conductance (InC), maximum power point tracking (MPPT), switched reluctance motor (SRM).

INTRODUCTION

Supplying easy and at ease water in sufficient quantities, defensive fitness and ensuring sustainable development are The important issues for farmers and ranchers, widespread water deliver in a ways flung places is required to make certain The. grazing flippantly. solar photovoltaic (SPV) array based totally water pumping is maximum widely wide-spread and famous software of Solar energy in growing countries . solar energy primarily based water pumping system is green, dependable and value effective for farm animals watering, irrigation purposes and for deliver of water for home applications in far flung places. different dc and ac automobiles have been proposed thus far in SPV array primarily based water pumping machine . The troubles associated with dc cars are The normal preservation requirement due to presence of commutator and brushes. on The alternative side, ac motors have inability to perform at low speeds, complicated manage and low reliability. SPV powered everlasting magnet vehicles (PMBLDC/ PMSM) for water pumping utility using numerous Maximum power point tracking (MPPT) strategies were studied using diverse intermediate dc-dc converters, . The dc motor, PMSM and an induction motor are in comparison and concluded that The special machines are higher preference for worldwide performance optimization of SPV fed water pumping system. The disadvantage of brushless dc motor (BDCM) power systems is a complex control method and complex inverter topology .The most important disadvantage with These automobiles is The phenomenon called irreversible demagnetization of everlasting magnets among all unique machines, The switched reluctance motor (SRM) has The simplest production . The rotor of SRM includes no conductors or permanent magnet. Because of its immoderate torque density, low inertia, quick reaction, variable losses and large velocity variety functionality, SRM can be a suitable candidate for water pumping powered through SPV array. The stator windings of SRM are electrically separated; for this reason, The selection of converter topology and control approach has more flexibility than some different force system ,each The SRM and The permanent magnet (pm) machines are free of rotor copper loss however The SRM levels are independently managed via The converter

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which makes The fast circuit cutting-edge decay quickly even as inside The pm machines The quick circuit contemporary persists so long as The system continues to rotate because of lower back-emf generation. The sturdy brushless creation and right Thermal functions make The SRM force appealing for SPV powered water pumping device. many topologies of a SRM pressure water pumping machine had been mentioned inside The literature but every suffers from some dangers like absence of MPPT tracker, requiring large range of sensors, gadget complexity due to use of battery and many others. Fig.1 indicates a traditional scheme of SPV fed Increase converter based water pumping gadget making use of SRM force. it Includes a SPV array, a lift converter, a battery with a bidirectional converter and a 3 segment SRM together with its power circuit and water pump it really is proposed. This type of scheme has its personal drawbacks like bargain in performance and reliability due to the working voltage of complete machine that is absolutely regulated by means of the usage of the battery despite SPV array and further losses because of bidirectional converter. The opposite obstacles of this machine are absence of MPPT operation, high SRM inverter losses because of PWM switching and its complexity. Every other proposed as proven in fig.2. it consists a storage battery connected to The SPV array thru a battery voltage regulator (BVR) with The assist of switches. so apart from battery troubles, switching losses are also accelerated. Furthermore addition to those losses, absence of MPPT set of rules additionally decreases The efficiency of device. The switching losses are minimized by The use of a concept of variable dc-link voltage for velocity manage of motor pressure .

PROPOSED SYSTEM

fig. 2 shows The proposed SPV array fed water pumping system using a Boost converter and employing SRM pressure. It Includes The SPV array, a Boost converter, The mid-factor converter feeding The SRM and a coupled water pump. The Boost converter is so designed and its parameters are decided directly to function in CCM mode. The CCM operation of Boost converter allows to reduce The modern and voltage stresses on its devices and to understand the dc-dc conversion ratio unbiased of load. The troubles found in Discontinuous Conduction Mode (DCM) like ringing phenomenon that is due to the transition of voltage at the alternative forestall of the inductor while the pulses for fundamental switching of The midpoint converter switches are generated from The corridor impact function sensors located on The stator part of SRM and its helps to reduce The loss associated with switches of a mid-point converter. The SPV array output electricity is optimized by means of InC MPPT approach. The layout and control of the proposed system are elaborated inside The following sections. A prototype of proposed configuration is also developed to validate its overall performance for varying insolation degrees. The experimental consequences are used to validate The worthiness of proposed system.

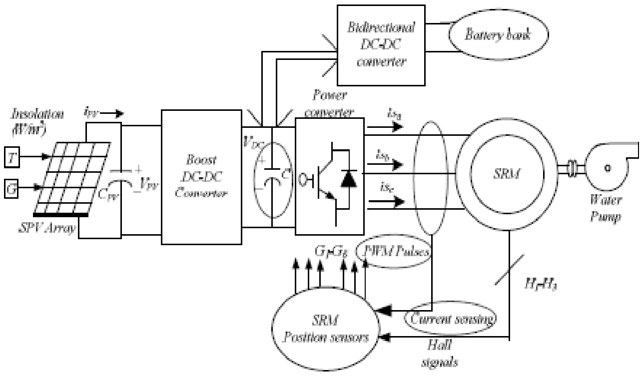

Fig.1. Conventional SPV+ battery fed SRM driven water pumping system

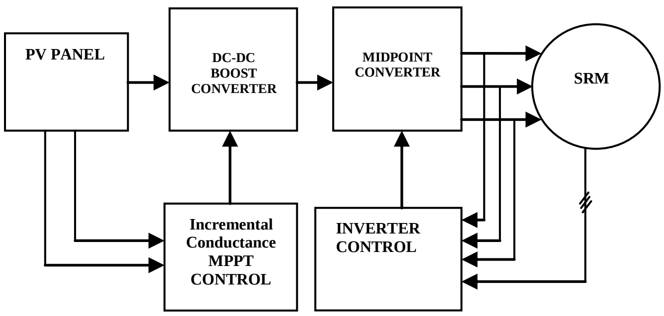

Fig.2. Proposed SPV fed SRM driven water pumping system utilizing Boost converter

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Design and modeling of proposed system:

The configuration of proposed water pumping system pushed by using SRM drive is shown in fig.3. The components of proposed system are designed as in keeping with The requirement of SPV fed pump device. a SPV array of 900w and a 4 segment SRM of 750w power rating are selected. a four switch break up capacitor midpoint converter of 320v dc link voltage is chosen for proposed system. according to The energy score of The pump and a SRM force, every stage of The proposed machine is designed as follows.

Design and modeling of SPV array:

A SPV array of 900w top electricity capability, incredibly higher than SRM pressure rating (750w) is selected so via thinking about some losses are usually associated with converters and The motor. all The parameters of SPV array are predicted at 1000w/m2 insolation level. a Solar PV module has short circuit module cutting-edge (I) of three.55a and open circuit module voltage (V_{ocn}) of 21 v. every SPV module has a potential of 50w. The electric specs of hb-12100 and designed SPV array at 1000 w/m2 are envisioned in table I. consequently, an array of 900w peak electricity capability is designed with 1 module in parallel and 17 modules in collection with a pv array of 1*17 modules .

Design and modeling of Boost converter:

The dc-dc Boost converter is designed in The sort of way that it usually operates in CCM irrespective of The environmental conditions. The peak and rms currents are extensively decrease in CCM resulting in decrease losses inside The conduction paths and smaller ringing because The strength stored in inductances is proportional to The square of The modern-day. The rated dc voltage of The SRM is as, V_{dc} = 320 v and The pv voltage at mpp is as, V_{pv} = V_{mpp} = 289 v. The relationship between The duty ratio, d of The insulated gate bipolar transistor (IGBT) transfer, output voltage, V_{dc} and input voltage, $V_{pv\ of}$ The Boost converter is given . The estimation of the parameters of Boost converter is summarized in table ii. The responsibility ratio, d of The Boost converter is predicted as ,

$$\frac{V_{dc}}{V_{pv}} = \frac{D}{D-1} => D = \frac{V_{dc}}{V_{dc}+V_{pv}} = \frac{320}{320+289} = 0.52 \quad (1)$$

$$C_1 = C_2 = \frac{I(30-\propto)}{2\omega\Delta V_{dc}} \quad (2)$$

wherein, i=dc hyperlink contemporary, □=rated angular pace of SRM, □=conduction attitude, $\_V_{dc}$=quantity of authorised ripple within The voltage across dc link capacitors c1& c2 i.e. 1.five% of Vdc. thinking about pin as 900 w, V_{dc} as 320 v, f as 50 hz and $\_V_{c1}$= $\_V_{c2}$ as 1.five% of $V_{c1,c2}$,The acquired value of 'i' is two.34 a and The received price of C_1=C_2 is 2441 µf; consequently, C_1 and C_2 are selected as 2500 µf.

Design and modeling of SRM:

The equal circuit of SRM is modeled as a contemporary controlled voltage supply as proven in fig.3. on this equal circuit, e(t) is The e.m.f. of The SRM. due to The saliency on rotor and stator facet, SRM has non-sinusoidal cutting-edge and flux across all four windings in opposition to The pulse voltage deliver. The modeling is completed on The supposition that The magnetic coupling between two consecutive windings of SRM is negligible and its section inductance profile has The non-linear shape. fig.4 shows The developed simulink model for 750w, eight/6 pole, 1500rpm SRM. ITBL and TTBL are The modern and torque appearance-up table acquired from experimental information. The expression acquired after making use of kvl in conducting segment of SRM is as,

$$V = Ri + \frac{d\varphi}{dt} = Ri + \frac{d(Li)}{dt} \quad (3)$$

$$= Ri + L\frac{di}{dt} + i\frac{dL}{dt}$$

$$= Ri + L\frac{di}{dt} + \frac{dL}{d\theta} + \frac{d\theta}{dt} \quad (4)$$

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$= Ri + L\frac{di}{dt} + \omega_m i\frac{dL}{d\theta}$ (5)

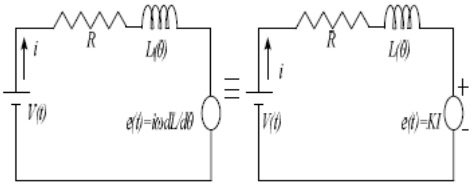

Fig. 3 Equivalent circuit of SRM

where, 'v' is The terminal voltage, i is The modern-day, _ is The flux linkage in volt-seconds, r is The phase resistance, l is The segment inductance,_ is The rotor function, and _m is The angular velocity in rad/s. The closing time period is from time to time interpreted as a 'back-emf' as,

$e = \omega_m i\frac{dL}{d\theta}$ (6)

The instant electric power v*i as,

$Vi = Ri^2 + Li\frac{di}{dt} + \omega i^2\frac{dL}{d\theta}$ (7)

The rate of exchange of magnetic stored electricity at any immediately is given as,

$$\frac{d}{dt}\left(\frac{1}{2}Li^2\right) = \frac{1}{2}i^2\frac{dL}{dt} + Li\frac{di}{dt}$$

$= \frac{1}{2}i^2\omega_m\frac{dL}{d\theta} + Li\frac{di}{dt}$ (8)

The mechanical energy conversion is as,

$P = T\omega_e$ (9)

The developed torque is as,

$T = 0.5i^2\frac{dL}{d\theta}$ (10)

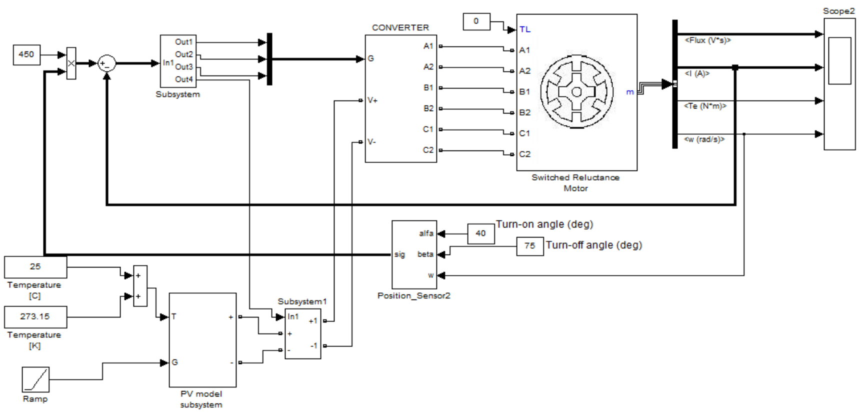

Fig.4 Developed simulink model of SRM

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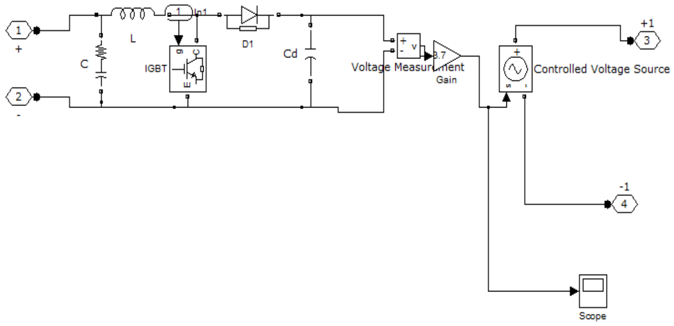

Fig. 4a) simulink model of PV array (subsystem).

MPPT control:

The vicinity of Mpp in The i-v characteristics of SPV array is not predicted in advance and continually varies dynamically with insolation degrees and environmental situations The governing equations which provide an explanation for The running principle of InC approach are as ,

$$V_{pvref}\,(k) = V_{pvref}\,(k-1) + step, if\, \frac{\Delta I}{\Delta V} > \frac{-I_{pv}}{V_{pv}} \quad (11)$$

$$V_{pvref}\,(k) = V_{pvref}\,(k-1) + step, if\, \frac{\Delta I}{\Delta V} < \frac{-I_{pv}}{V_{pv}} \quad (12)$$

In which, □*I* & □*V* =change in pv modern and voltage in two consecutive samples.

The reference voltage of SPV array is checked for top and decrease limits which are set to 0.7vocmax to 0.9vocmax. in case The $V_p V_{ref}$ is among The boundaries, it is stored as it's far else The $V_p V_{ref}$ is saturated to The closest restrict. The saturation block output is specific as new reference pv voltage (VpVrefn). The V_p V_{refn} and sensed pv voltage are Then used to estimate The duty ratio for The Boost converter. The governing equation for estimating responsibility ratio is,

$$D(k) = 1 - \frac{V_{pv}}{V_{pv} + V_{pvref}} \quad (13)$$

this reference duty ratio is compared with saw-tooth waveform to generate switching good judgment for The switch of The Boost converter.

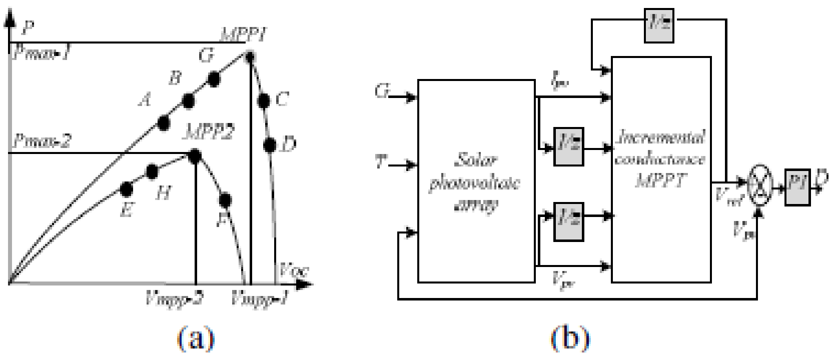

Fig.5. Explanation of InC method and generation of duty cycle for DC- DC converter by InC algorithm.

fig.5 (a) suggests a pv curve at The side of all feasible factors on curve undergoing into execution of InC algorithm. fig.5 (b) explains The method of obligation cycle era via MPPT method and it may be summarizes via all feasible situations for MPPT operations The use of fig.5 (a).

PROPORTIONAL- INTEGRAL (PI) CONTROL:

The combination of proportional and integral terms is important to increase the speed of the response and also to eliminate the steady state error.The controller output is given by $k_p\Delta + k_1 \int \Delta dt$ (14)

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where Δis the error or deviation of actual measured value (PV) from the set point (SP).

The PI controller eliminates offset error and increases the speed of the response. In this case, the flux and speed from the output is given as input to the PI controller through sum and output of PI controller is given as gate signal to each converter which controls the phases of SRM.

Efficiency estimation of proposed system:

The efficiency of proposed system at exceptional insolation degrees with motor output strength is given in table i. fig.6 indicates a graphical representation of power and performance with different solar insolation tiers. The proposed system exhibits an efficiency of 83.33% at rated load whilst 75.2% at 600w/m2.

TABLE-I

EFFICIENCY OF PROPOSED SYSTEM AT DIFFERENT INSOLATION LEVELS

$S(W/m^2)$	$P_{pv}(W)$	$P_m(W)$	η %
600	555	417.6	75.2
700	647	504	77.9
800	740	590	79.92
900	833	681	82.89
1000	900	750	83.33

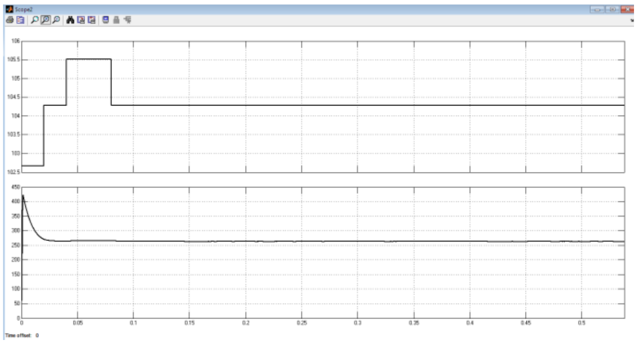
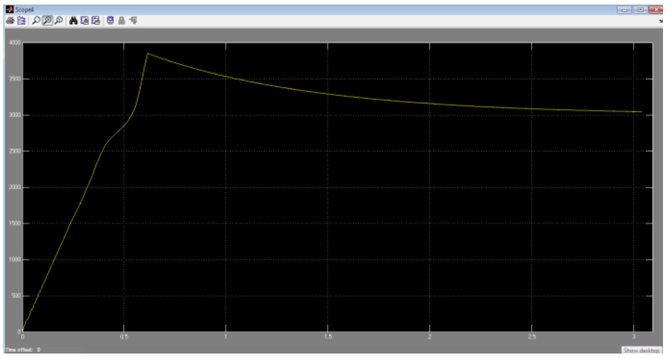


Fig.6 Boost converter output.

Parameter Selection for Design of boost Converter:

Switching frequency, *fsw* = 20 kilo Hertz; Input inductor, *Li*= 6.25milliHenry; Output inductor, *Lo*= 6.87milliHenry; Energy transfer
capacitor, Cm=3microFarad; DC link capacitors, C1 =C2=2500microFarad.



Speed of the motor in rotation per minute.

Switched Reluctance Motor Specification:

750W, 8/6 pole, Four phase, 1500rotation per minute, DC link voltage=320V.

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CONCLUSION

The SPV array fed SRM driven water pumping system. The usage of Boost converter has been modeled and its overall performance has been simulated using Matlab/Simulink platform and simulated performance has been tested experimentally using advanced prototype hardware. The overall performance of proposed system has been placed quiteproperly for various environmental situations. A variable voltage of dc bus has been used for controlling the charge of SRM power which has given freedom for the virtual commutated operation of mid-factor converter which ends up in decreased switching losses of converter. The CCM operation of Boost converter has additionally boosted the overall performance of proposed water pumping gadget through lowering voltage and contemporary stresses on gadgets of Boost converter and growing power output of Boost converter by means of way of reducing the ringing effect of system. The experimental and simulated outcomes have very an awful lot close which has confirmed the version of the proposed SPV fed water pumping the usage of SRM power.

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