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Enhancement of Efficiency of Air Conditioner Using Switched Reluctance Motor

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Abstract: In the conventional air conditioning system, induction motors are used for driving the compressor. The main problem of AC(Alternating current) supply while using an inductive load is low power factor, presence of plentiful harmonics at the ac input side and it requires high starting current. Here the induction motor is replaced with an SRM (Switched reluctance motor), and thus the system can be used for low power solar applications. The efficiency of a switched reluctance motor is more compared to a conventional induction motor. In air conditioning system, using inverter technology as drive circuit for induction motor, DC is obtained at the second stage of the inverter circuit. This DC supply can be used to drive the Switched reluctance motor and thus the cost of additional drive circuit can be compensated. SRM has relatively high starting torque compared to induction motor with minimum starting current, which makes it more suitable for air conditioning system, which further enhances the power quality for the power distribution system. Further, the SRM can be used in places where DC grid exists, i.e. in a train. Conventionally, induction motors are used in a train to drive its air conditioning system. And the DC supply is inverted and fed to the induction motor. Replacing induction motor with Switched reluctance motor in air conditioning system of train will improve the overall efficiency of the system and thus reduce the running cost. Life expectancy of a SRM is comparable to that of an induction motor. So, SRM can be used in place of induction motor in these applications.

Keywords: air conditioners, induction motors, switched reluctance motor, perturb and observe

I. INTRODUCTION

In the conventional air conditioning system, induction motors are used for driving the compressor [1]-[3]. The main problem of AC(Alternating current) supply while using an inductive load is low power factor, presence of plentiful harmonics at the ac input side and it requires high starting current. Here the induction motor is replaced with an SRM (Switched reluctance motor), and thus the system can be used for low power solar applications. The efficiency of a switched reluctance motor is more compared to a conventional induction motor [4]. In air conditioning system, using inverter technology as drive circuit for induction motor, DC is obtained at the second stage of the inverter circuit. This DC supply can be used to drive the Switched reluctance motor and thus the cost of additional drive circuit can be compensated. SRM has relatively high starting torque compared to induction motor with minimum starting current, which makes it more suitable for air conditioning system, which further enhances the power quality for the power distribution system [5]-[7]. Further, the SRM can be used in places where DC grid exists, i.e. in a train. Conventionally, induction motors are used in a train to drive its air conditioning system. And the DC supply is inverted and fed to the induction motor. Replacing induction motor with Switched reluctance motor in air conditioning system of train will improve the overall efficiency of the system and thus reduce the running cost. Life expectancy of a SRM is comparable to that of an induction motor [8]-[9]. So, SRM can be used in place of induction motor in these applications.

The three phase induction motors are the most widely used machines in several industrial and manufacturing processes. Nowadays these motors have become a promising source which can provide about 80% of the mechanical power output in the industries [10]-[12]. The applications of these motors are now been extended and is used in escalators, paper industries, hoists, lathe machines, textiles etc. Over the years, the cost of drive systems is decreasing with an increase in their performance. Owing to the advantages such as high efficiency, ease of operation, durability, absence of commutator and brushes when compared to DC machines, induction machines are now widely accepted for many purposes [13]. Induction motors have a wide variety of applications which will ranges from pumps, elevators, presses

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to applications even in hazardous environments like petrochemical and natural gas plants. Even if induction machines have many advantages, they also have many drawbacks such as speed control is difficult since it is a constant speed motor, high starting current, occurrence of common mode voltages etc.

The Switched Reluctance Machines are receiving significant attention from industries, because of its inexpensive manufacturability; simple structure and reliability make it superior to other electric machines [14]-[15]. The system performance was verified with the presence of Switched Reluctance Motor (SRM) drive system at load side. Also the SRM need no rare earth materials. The switched reluctance motor (SRM) is a type of a stepper motor, an electric motor that runs by reluctance torque. Unlike common DC motor types, power is delivered to windings in the stator (case) rather than the rotor. This greatly simplifies mechanical design as power does not have to be delivered to a moving part, but it complicates the electrical design as some sort of switching system needs to be used to deliver power to the different windings [16]. With modern electronic devices, precisely timed switching is not a problem, and the SRM is a popular design for modern stepper motors. Its main drawback is torque ripple.

II. OPERATION OF PROPOSED SYSTEM

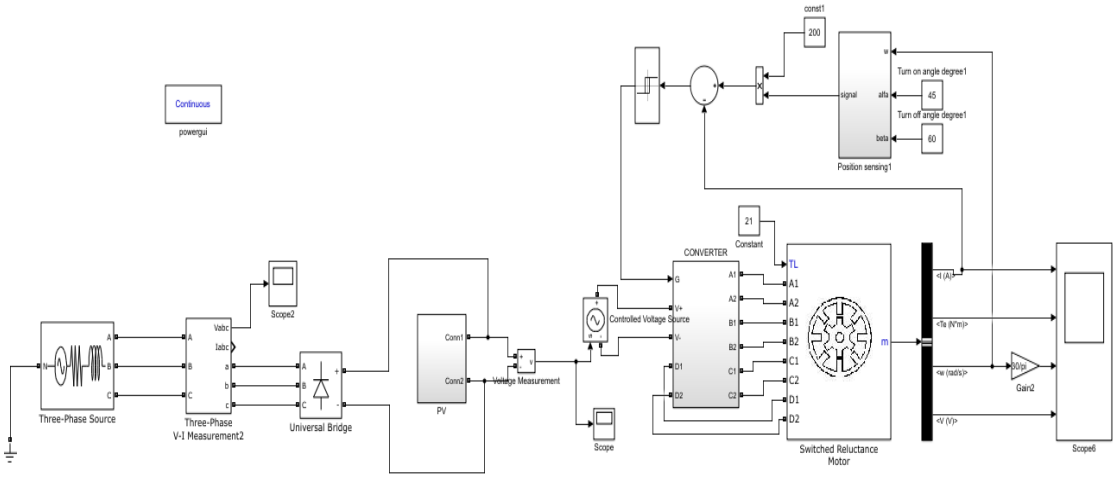

Fig.1. Proposed SRM based drive circuit for air conditioning system

In the conventional air conditioning system, induction motors are used to drive the compressor. Induction motors are inferior to Switched reluctance motors, since the overall efficiency of induction motor is less than that of Switched reluctance motor. Induction motors reduces power factor of the transmission system. In modern inverter fed air conditioner system, the overall efficiency is improved when compared to that of conventional air conditioner system. It consist of an AC-AC converter which controls the frequency of the power fed to induction motor. The speed of the compressor fed by induction motor is controlled by controlling the frequency of the supply voltage with the help of AC-AC converter. It is one among the most efficient way controlling induction motors. But due to the presence of switching circuits, it introduces a lot of harmonics into the transmission system and the overall power quality of the transmission system is affected. Moreover, the introduction of AC-AC converters in the system increases the overall cost of the air conditioners. And the reliability of the system is reduced due to the presence of a lot of electronic components.

In the proposed system the induction motor is replaced with Switched Reluctance Motor. Fig.1 shows the Proposed SRM based drive circuit for air conditioning system. The MATLAB modelling of the air conditioning system with Switched Reluctance Motor is modelled to compare the overall difference in efficiency of the two systems. SRM driven systems are more suitable in systems where DC supply is used. In Trains, DC supply is used and therefore, it is more applicable in trains. Thus the cost of implementation of AC-DC converters is reduced. For a DC Grid system, the Factors such as harmonics and power quality has less impact and the quality of DC supply can be easily improved when compared to that of AC Supply.

In this system the SRM is fed both from Mains and Solar power. The capacity of the air conditioner is 3Tonnes and the Photovoltaic system is designed to deliver a peak power of 4100Wp. The Mains supply and the Photovoltaic supply is connected in parallel to SRM converter circuit. The power delivered is shared by the Mains and the PV system. The AC power from Grid is converted to DC supply with the help of a converter. The overall power consumption of SRM is compared with that of the power consumption of induction motor driven air conditioning system.

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III. MODELLING OF PHOTOVOLTAIC MODULE

The photovoltaic system can generate direct current electricity when it is exposed to sunlight. The basic building block of PV module is the solar cell, which is basically a p-n semiconductor junction which is shown in Fig.2. The V-I characteristic of a solar cell is given by Eq. (1)

$$I = I_{ph} - I_s \left[\exp\left(\frac{q(V+I_{rs})}{kT_cA}\right)-1\right] - \frac{V+I_{rs}}{R_{sh}} \qquad (1)$$

I_{ph} : Photocurrent function
k : Boltzmann's constant,($1.38*10^{-23}$J/K)
T_{rf} : Reference temperature
Tc : Actual temperature
Irs : Reverse saturation current
q : electron charge (1.6*10-19 C)
k : Temperature coefficient
V : Terminal voltage
A : Ideal factor

In this paper the P & O (perturb and observe) MPPT algorithm has been simulated.

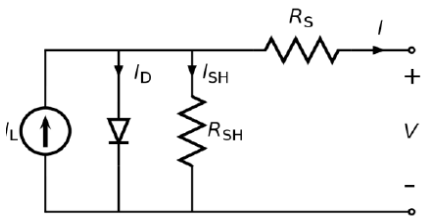

Fig. 2. Equivalent circuit of a solar cell

Maximum power point tracking (MPPT) is a control technique to adjust the terminal voltage of PV panels so that maximum power can be extracted. The MPP may change due to external factors such as temperature, light conditions and workmanship of the device. Main dependent factor of MPPT is temperature and irradiance.

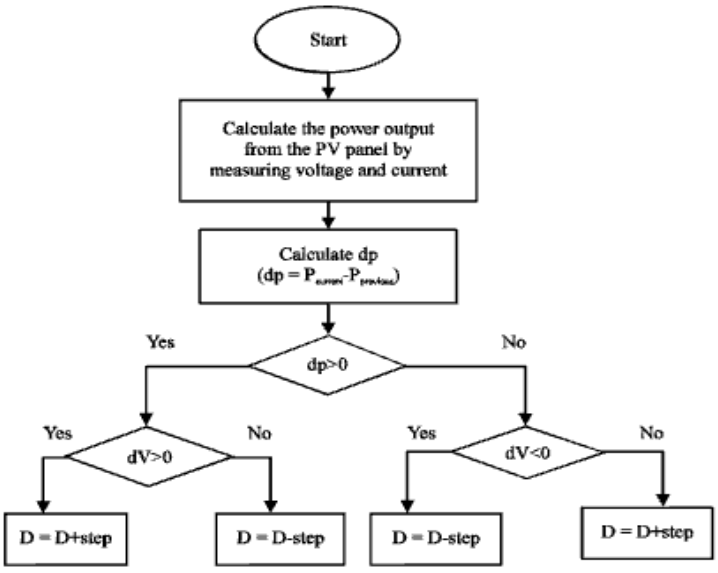

Fig. 3. Flow chart of P&O MPPT

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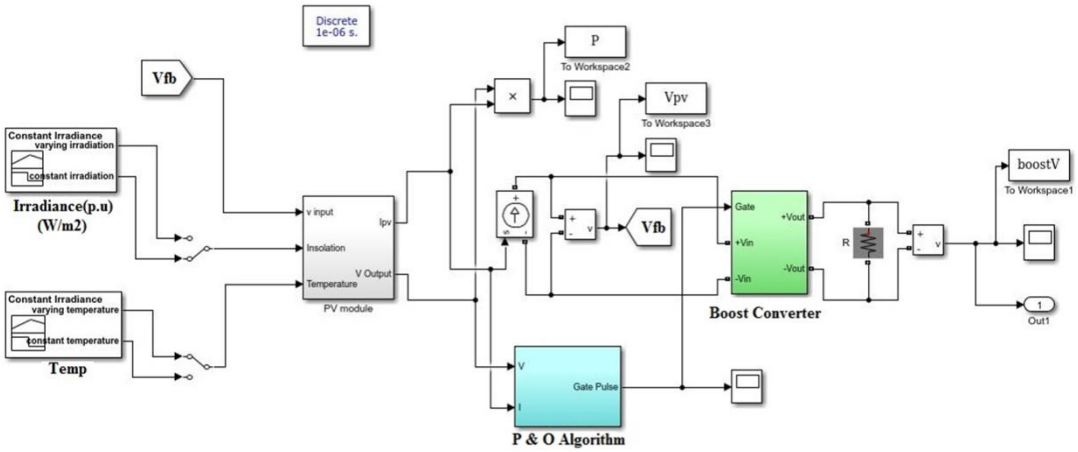

Fig.4. Modeling of PV

It is referred to as a hill climbing or P & O method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Fig.4 shows the modelling of PV. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted.

TABLE I SPECIFICATION OF SIMULATED PV MODULE

Peak power(Pm)	4,176 W
Open circuit voltage(Voc)	290 V
Short circuit current(Isc)	14.4 A
Operating temperature	25°C

IV. MATLAB/SIMULINK RESULTS AND DISCUSSIONS

The modelling of photovoltaic system for SRM driven Air conditioner is conducted. The capacity of photovoltaic system is 4176Wp. Fig. 5 shows the peak value of current generated from PV system at optimum condition. The maximum value of current (Isc) is obtained to be 14.4 A. The values are measured at a temperature of 25oC and at rated voltage of 290V.

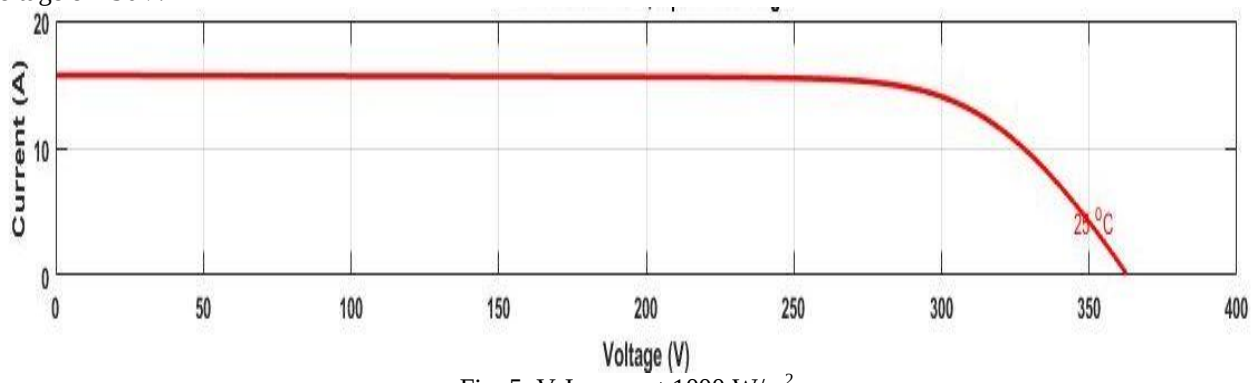

Fig. 5: V-I curve at 1000 W/m^2

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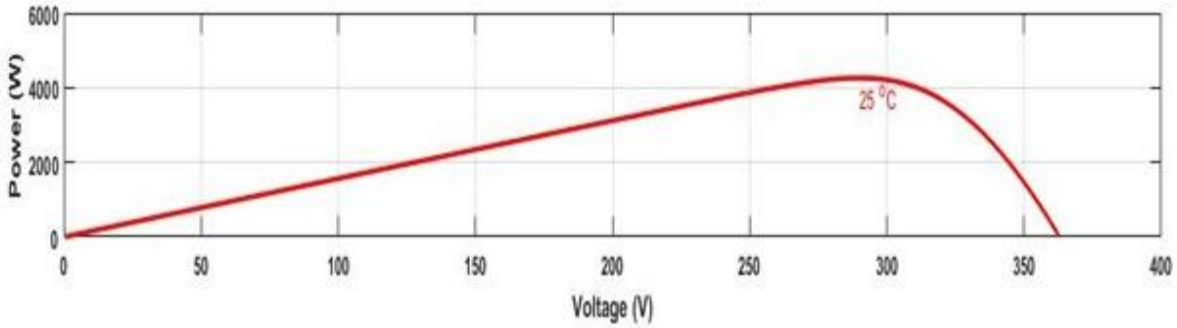

Fig. 6: P-V curve at 1000 W/m^2

The load torque of the motor depends upon the load applied to the motor. The load torque is determined with the help of the following equation. The rated speed of the machine is 1500 RPM. The capacity of machine is 3 Tonne. Equivalent power of the motor is 3300W.

Load torque = (HP * 5252)/RPM

Load torque = (4.4 * 5252) / 1500

= 15.43 Nm

From fig. 7 & 8, the Load torque is 15.43 Nm and the rated speed of the machine is 1500RPM.

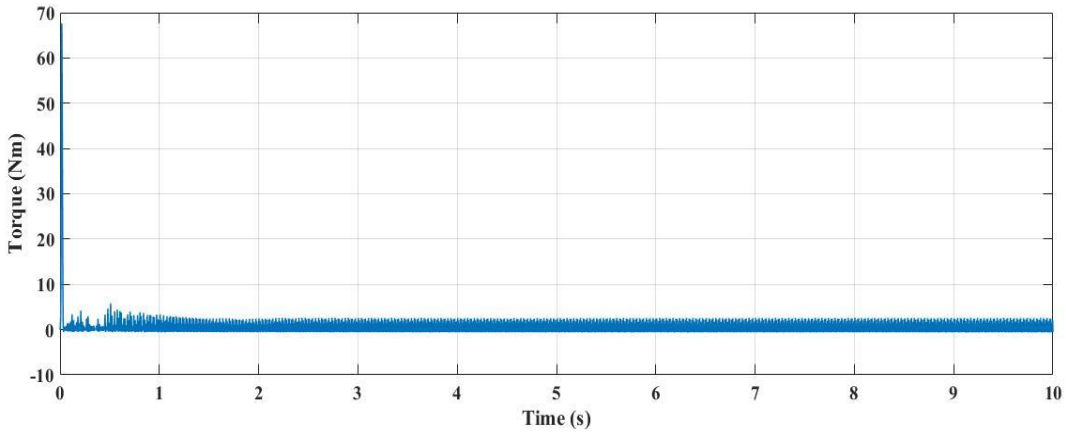

Fig. 7: Torque of SRM

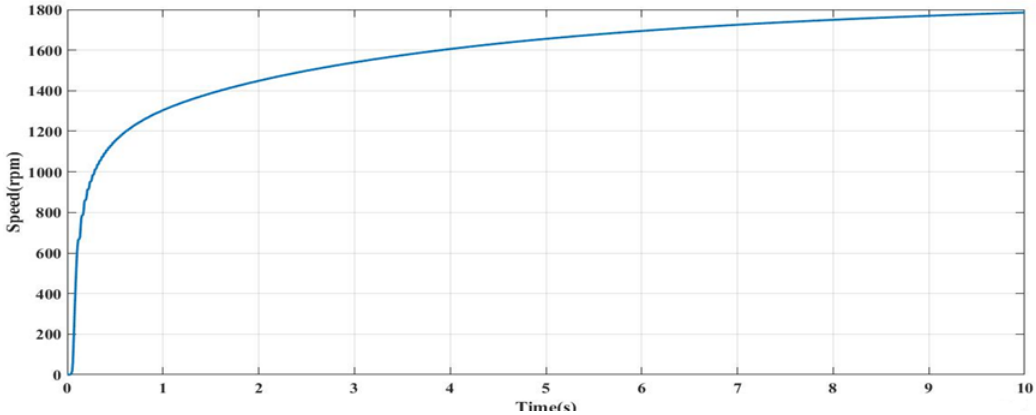

Fig. 8: Torque of SRM

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V. CONCLUSION

The MATLAB modelling of SRM driven air conditioning system is performed to analyse the improvement in efficiency when conventional induction motor is replaced with switched reluctance motor. The comparison of efficiency of induction motor driven air conditioner and SRM driven air conditioner is conducted to estimate the difference in performance of the air conditioning system. In the conventional air conditioning system, induction motors are used for driving the compressor. The main problem of AC(Alternating current) supply while using an inductive load is low power factor, presence of plentiful harmonics at the ac input side and it requires high starting current. Here the induction motor is replaced with an SRM (Switched reluctance motor), and thus the system can be used for low power solar applications. The efficiency of a switched reluctance motor is more compared to a conventional induction motor. SRM has relatively high starting torque compared to induction motor with minimum starting current, which makes it more suitable for air conditioning system, which further enhances the power quality for the power distribution system. Further, the SRM can be used in places where DC grid exists, i.e. in a train. Conventionally, induction motors are used in a train to drive its air conditioning system. And the DC supply is inverted and fed to the induction motor. Life expectancy of a SRM is comparable to that of an induction motor. So, SRM can be used in place of induction motor in these applications. Modelling of induction machine is done and the output waveforms are analysed. The study of modelling of proposed system with SRM is going on.

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