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Design of Solar Water Pumping System with FCMA Soft Starter

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Abstract: This paper presents a novel stand-alone solar powered water pumping system, especially suited for usage in rural or remote areas. In this scheme, inverter drives the induction motor, which drives the water pump. Moreover, the starting ability of an induction motor becomes quite poor due to the drop in the system voltage when the motor starts. For these reason, overall efficiency of an induction motor based drive systems supplied by a PV array is lower. To obtain maximum output power of the solar panel, the inverter is operated at soft start to minimize starting current of motor by using FCMA technology. The use of FCMA helps in variable speed controls, increasing the life of components and reducing the capital cost & maintenance. It also assists in enhancing motor efficiency.

Index Terms: FCMA, Induction Motor, Photovoltaic, Solar Pump, Soft Start.

I. INTRODUCTION

As the non renewable sources are rapidly decreasing and the demand is increasing continuously. Solar photovoltaic energy is one of the solutions for this problem. Photovoltaic powered systems are becoming increasingly popular due to- i) The absence of the power line near the water pumping sites in remote areas, frequent shortage of electrical power. ii) Environmental degradation caused by fossil fuel. iii) High cost of fossil fuel based electricity. iv) Low cost of fossil fuel based electricity. Now-a-days more focus is done on renewable energy sources. Growth has been experienced over few past decades because of exhaustion of fossil fuels; energy security is another aspect need to be paid attention. Many International Agency for Energy has reported that in near future more over 60% of generation will be through renewable energy source. There are many forms of renewable energy source available, in which Photovoltaic generation is much flexible and easy to use either for domestic or industrial application or in commercial application. PV array receives energy from the sunlight & generates electric power, which is fed to 3 phase induction motor via inverter & FCMA unit. 3 phase induction motor is considered because of its reliability, dependability, low value & low maintenance cost. However, the use of squirrel cage induction motor is receiving increasing attention because of their reliability and maintenance free operation. Induction motors do not have the commutators and brushes that are blamed for most of the problems that occur in dc motors. The main disadvantages of PV array powered, induction motor drive system is the efficiency of the induction motor is not as high as that of the dc motor. Output requires a variable speed control since the motor required a soft start & the sun constantly changes its position so power generated by stationary PV cells varies accordingly, due to different voltge situation, motor don't produce maximum torque. Therefore, by using FCMA technology supply voltage and speed should be changed.

In typical PV panel the voltage range is about 20 to 50V. Such small level of voltage cannot run any equipment hence needs to be step up up to usable range. So by using inverter and transformer, voltage is step up to constant 415 V AC. If output voltage has to increase several PV modules are connected in parallel. For utility ac supply is generated by using inverter & transformer.

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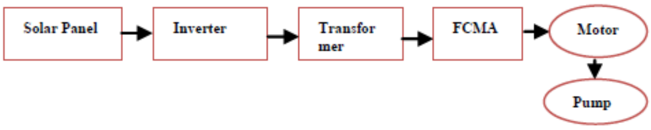

Fig:1 Block diagram of solar water pump with FCMA

II. SYSTEM DESIGN & ANALYSIS

i) An design a PV water pumped system to determine the amount of water to be pumped i.e. 48meter cube/day ii) Hydraulic power/ Pump power = Q*TDH* density *g. Q is the flow rate in meter cube per day, TDH is the total dynamic head in meter, density of water in Kg per meter cube, & g is acceleration in meter per sec-square. So, Q=48 m^3 /day, TDH=18 m, density=1000 kg/ m^3, g=9.8m/ s^2, power = 48*18*1000*9.8 (multiply by 1/3600 to convert in second in hours) = 2354.4 watt-hour/day. iii) Solar radiation data=6 hours/day (peak of 1000 W/ M^2) iv) Solar radiation data=6 hours/day (peak of 1000 W/ M^2) panel=total hydraulic energy /No. of hours of peak sunshine /day = 2354.4/6 = 392.4 watt. System losses = Total PV panel wattage /pump efficiency * mismatch factor =392.4/ (.6*.85) = 769.4, considering operating factor = Total PV panel wattage after losses/operating factor=769.4/.75 = 1026 watt i.e. also PV panel capacity so number of PV panel required = 1026/200 ~= 6. Power rating of motor= 1026/746 ~= 2 HP motor

Table I. Specification of Induction Motor

Parameter	Values
Number of poles	4
Phase	3
Rated power	1.5 kW
Rated voltage	415 V
Rated current	3.2 A
Supply frequency	50 Hz

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Rated speed	1470 rpm
Power factor	0.81

III. FCMA TECHNOLOGY

FCMA (flux compensation magnetic amplifier) benefit the pumping scheme as follows: i) Reduced starting current & limits voltage drop. ii) Harmonic free starting and running. iii) Transformer can be sized for running power and need not be larger only for starting consideration. iv) Smooth starting can increase component life. v)It is possible to improve design efficiency of the motor by relaxing the direct online starting current limit. vi) By using tap of FCMA, we can adjust the voltage supply to motor.

The fundamental function of the soft starter is to accelerate the motor combination smoothly with the least possible starting current value and in the optimum time. The pump represent the load, which is defined by its torque speed characteristics during starting and rotating inertia. The relationship between the load torque demand and speed is parabolic nature governed by the following equation:

$$T \alpha N^2$$

Where T represents the torque demand and N represents the load speed. It is ensured through FCMA that the motor torque is always larger than the load torque demand by 0.1 per unit ensuring gradual and continuous acceleration.

The FCMA soft starter work on the principle of impedance control. FCMA consists of two windings wound on a common magnetic core. The first winding is called the main winding and is connected in series with the motor winding as shown in fig. and carries the main motor current. The second winding is called the feedback winding or compensating winding and is wound with a polarity opposite to the main winding. This winding is excited with the counter electromotive force (emf) generated by the motor. The core is subjected to two simultaneous sinusoidal fluxes opposing each other due to the magneto motive force (mmf) created by the main and compensating windings. As both the fluxes are sinusoidal in nature, the net flux in the core is sinusoidal. As the motor speed increases the compensating flux increases, thus reducing the net flux in the core. The impedance of the main winding hence decreases with motor speed, to keep the motor current constant and increment the motor voltage. The voltage increment is obtained by correcting the natural drop in the motor current with speed. Thus the effective motor voltage increases from a low value (typically 50 percent) at start, to near full value (typically 95 percent) when the motor reaches full speed. As the FCMA impedance varies in a stepless manner the voltage increment is also stepless. The voltage increment feature is very advantageous for acceleration of centrifugal drives such as load, because the load torque demand also increases with speed, in a near parabolic fashion. The FCMA core is always subjected to alternating fluxes and works in the linear zone, thus ensuring that the voltage and current waveforms are purely sinusoidal in nature and totally harmonic free. When the drive accelerates to full speed the run mode contactor bypass the FCMA with closed transition. FCMA soft starters control the amplitude of motor current without distorting the current waveform. This leads to zero harmonics and substantially low starting current.

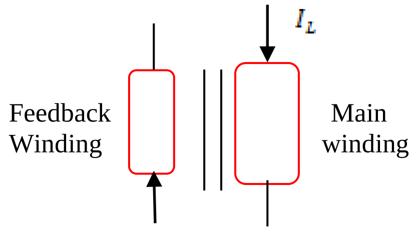

Fig 2: Flux compensation principle

$$I_C \, \alpha \, C_{emf}$$

$\Phi_m = \Phi_m \sin\theta$ ---- Main flux

$\Phi_c = \Phi_c \sin(\theta - 180)$ ---- Compensating flux

$\Phi_T = \Phi_m + \Phi_c$ ---- Net flux

$\Phi_T = \Phi_m \sin\theta - \Phi_c \sin(\theta - 180)$ ---- Net flux

As the motor speed increases, the compensating flux increases, thus reducing the net flux and hence reducing the impedance of the FCMA.

IV. RESULT

Case I: Starting curve of motor driven pump (i.e. current vs. speed curve and torque vs. speed curve) with FCMA soft starter at 40% voltage. Starting current is 2.4 p.u.

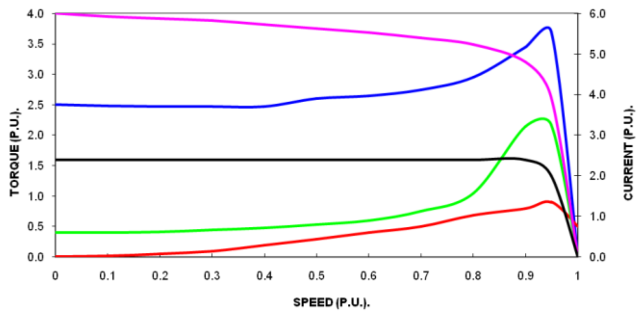

Fig 3: Starting curve for motor driven pump with FCMA soft starter at 40% voltage.

Case II: Starting curve of motor driven pump (i.e. current vs. speed curve and torque vs. speed curve) with FCMA soft starter at 50% voltage. Starting current is 3 p.u.

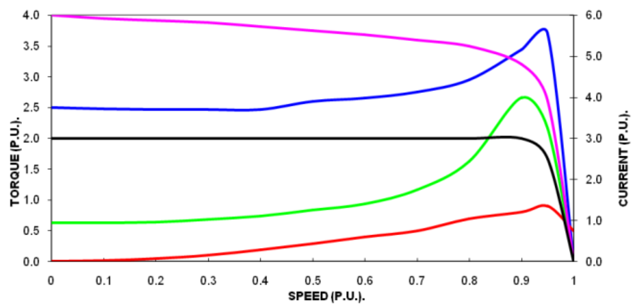

Fig 4: Starting curve for motor driven pump with FCMA soft starter at 50% voltage.

Case III: Starting curve of motor driven pump (i.e. current vs. speed curve and torque vs. speed curve) with FCMA soft starter at 60% voltage. Starting current is 3.6 p.u.

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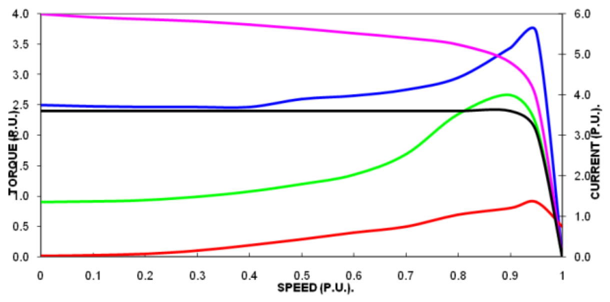

Fig 5: Starting curve for motor driven pump with FCMA soft starter at 60% voltage.

Table 2: FCMA Soft Starter Results

% voltage to motor	Voltage to motor (V)	Voltage across FCMA (V)	Starting current (amp)	Impedance (Ohm)
40	166	249	8	18.72
50	208	208	10	12.48
60	249	166	12	8.32

Table 3: Transformer Selection

Description	Transformer Sizing
Transformer selection with DOL	9200 VA
Transformer selection with FCMA soft starter	3700 VA

From above table leads to modify transformer sizing with FCMA soft starter reduced by 60%.

V. CONCLUSION

FCMA soft starter approach to improve the efficiency and operating performance of induction motor based drive systems supplied by PV arrays. This paper proposed solar photovoltaic array fed water pumping system is operated at different voltage condition. The use of FCMA helps in optimization systems, increase the life of components, and increase the motor efficiency. To obtain maximum output power of the solar panel, the inverter is operated at FCMA soft start to minimize stall current of motor. Transformer and inverter can be sized for running power and need not be larger only for starting consideration. Starting current of motor driven pump with FCMA soft starter is found to be comfort and at 40% of voltage. This leads to modify transformer sizing by 60% reduced size.

REFERENCES

1. P Sadasivam, M Kumaravel, Krishna Vasudevan and Ashok Jhunjhunwala, “Analysis of Subsystems Behaviour and Performance Evaluation of Solar Photovoltaic Powered Water Pumping System,” IEEE transaction paper – 2013
2. Rayyan Azam Khan, Liaquat Ali Khan, Syed Zahid Hussain, “Design and Simulation of 0.75hp Soft Start AC Water Pump Powered by PV Solar System,” Universal Journal of Mechanical Engineering 3(4): 113-121, 2015
3. Geet Jain, Arun Shankar V.K., Umashankar S, “Modelling and Simulation of Solar Photovoltaic fed Induction Motor for Water Pumping Application using Perturb and Observer MPPT Algorithm,” IEEE transaction paper – 2016.
4. Mikhail Tsypkin, “Vibration of Induction Motors Operating with Variable Frequency Drives - a Practical Experience,” IEEE 28-th Convention of Electrical and Electronics Engineers in Israel-2014.
5. Flavio Palmiro, Joao Onofre Pereira Pinto, Lucio Henrique Pereira, Ruben Barros Godoy, “Cost Effective Photovoltaic Water Pumping System for Remote Regions Communities,” IEEE Transactions-2016.
6. A.Betka, A.Moussi, “Optimized Solar Water Pumping System Based On Induction Motor Driving Centrifugal Pump,” IEEE Transactions On Industry Applications, Nov-2001.
7. Y.Yao, P.Bustamante, R.S.Ramshaw, “Improvement of Induction Motor Drive Systems Supplied By Photovoltaic Arrays With Frequency Control,” IEEE Transactions Energy Conversion, Vol.9, No. 2, June- 1994.
8. S.R.Bhat, Andre Pittet, B.S.Sonde, “Performance Optimization of Induction Motor Pump System Using Photovoltaic Energy Source,” IEEE Transactions On Industry Applications, Vol. IA-23, Nov-1987.
9. Eduard Muljadi, Roger Taylor, “PV Water Pumping With Peak Power Tracker Using Simple Six Step Square Wave Inverter,” IEEE Transactions Energy Conversion, Nov-1996

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