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A High-Performance Single-Stage Photovoltaic Solar Pumping System Under partial Shading Conditions (PCS) using a Horse Herd Optimization Algorithm (HOA)

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INTRODUCTION & AIM

Solar energy for water pumping in remote areas is gaining popularity globally. Traditional systems are costly and less efficient due to double-stage solar conversion. Research now focuses on single-stage conversion using a VSI for motor control, eliminating the need for a DC-DC converter. However, optimizing energy extraction from solar panels is crucial. Various Maximum Power Point Tracking (MPPT) methods, such as P&O, CSA, FPA, GWO, and HOA, enhance energy harvesting from PV modules. Yet, challenges arise when partial shading occurs due to factors like buildings, clouds, and trees, resulting in multiple power points, including the global maximum power point (GMPP) and local maximum power points (LMPP). Achieving GMPP becomes particularly challenging under such conditions. This study presents a simulated standalone solar water pumping system model with predictive control for motor operation using MATLAB/Simulink. The system's performance has been tested Under the use of The previously mentioned methods. The HOA algorithm demonstrated fast, robust, and accurate performance in tracking the GMPP. On the other hand, the PTC provided good performance in controlling the inverter to achieve the required reference speed, allowing for a good flow water rate. Combining the extraction of GMPP from a solar panel with on-robust control of the motor results in a high-performance system.

METHOD

- The Horse Herd Optimization Algorithm (HOA) is implemented in software blocks with inputs of current and voltage readings from a PV module. The algorithm calculates the optimal frequency for maximum power extraction, which is then used in the control mechanism. Various variables are initialized, and fitness values are computed based on initial conditions to update horse velocities and frequencies. Horses are categorized based on their fitness, with specific parameters influencing their behavior. The algorithm determines horse positions based on fitness, updating velocities and positions accordingly. The aim is to guide horses towards optimal frequencies for power maximization. The algorithm continuously updates velocities and positions until maximum power is achieved, maintaining the best horse position. This process repeats until a stopping criterion is met, like reaching a specified counter limit. The cycle continues until a predefined condition is satisfied, such as reaching a specific iteration counter limit.
- The PTC method involves estimating unmeasurable variables, predicting stator flux and torque, and designing a cost function. Stator flux estimation can utilize various observers. The predictive algorithm calculates the next-step stator flux and electromagnetic torque using forward Euler discretization. The classical cost function includes parameter tuning and minimization for optimal output vector selection. The inverter in the system has 8 switching states but only 7 voltage vectors, resulting in 7 different values for the cost function. The output vector is determined based on minimizing the cost function.

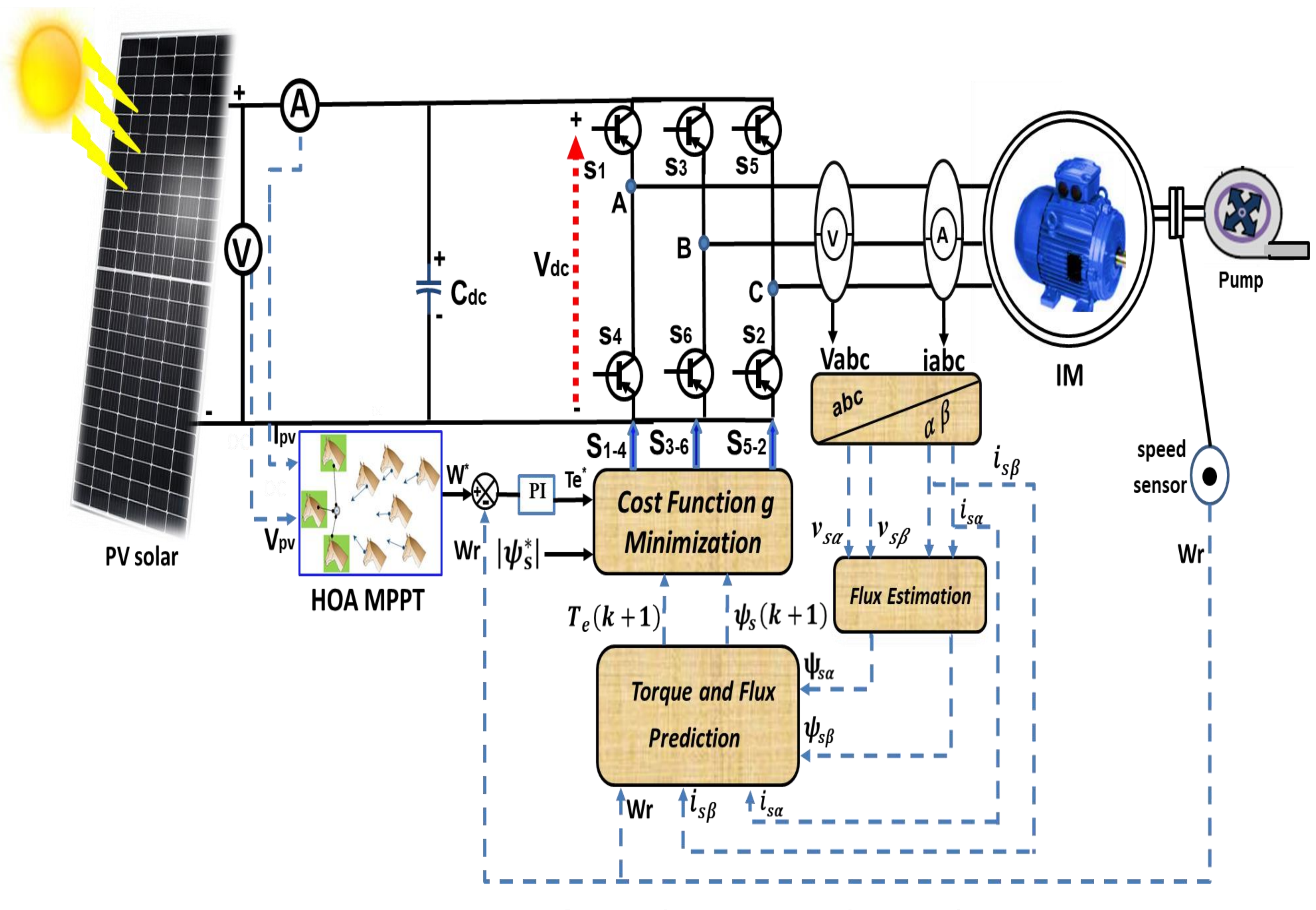
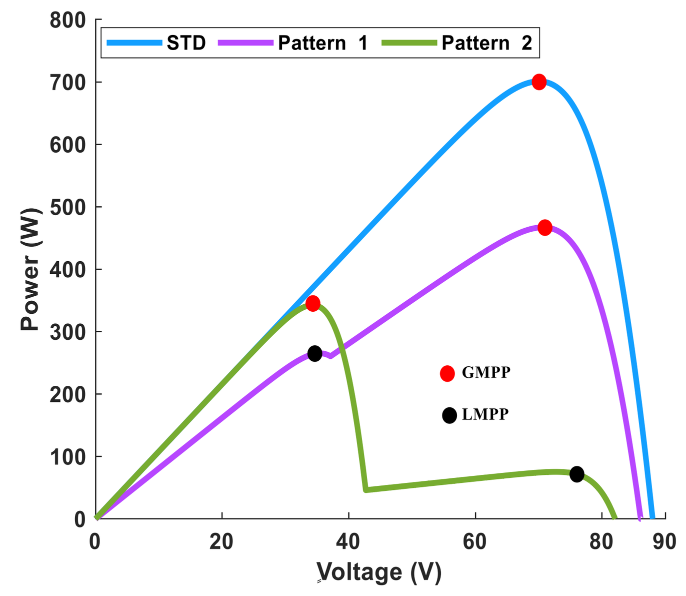


Fig. 2 The proposed PV solar

RESULTS & DISCUSSION

The proposed configuration for the system has been simulated in MATLAB/Simulink . Which the system consists of four PV modules connected in a 2 (series)×2 (parallel).

- STD PV was shaded with 1000 W/m² has a GMPP of 700W.
- Pattern 1 upper PV was shaded with 900 and 500 W/m², lower PV with 900 and 500 W/m² and has a GMPP of 487.5 W and LMPP of 267.52 W
- Pattern 2 , the top PV had shading of 900 and 900 W/m², bottom PV of 100 and 100 W/m²,and has a GMPP of 307.2 W and an LMPP of 60.4 W.



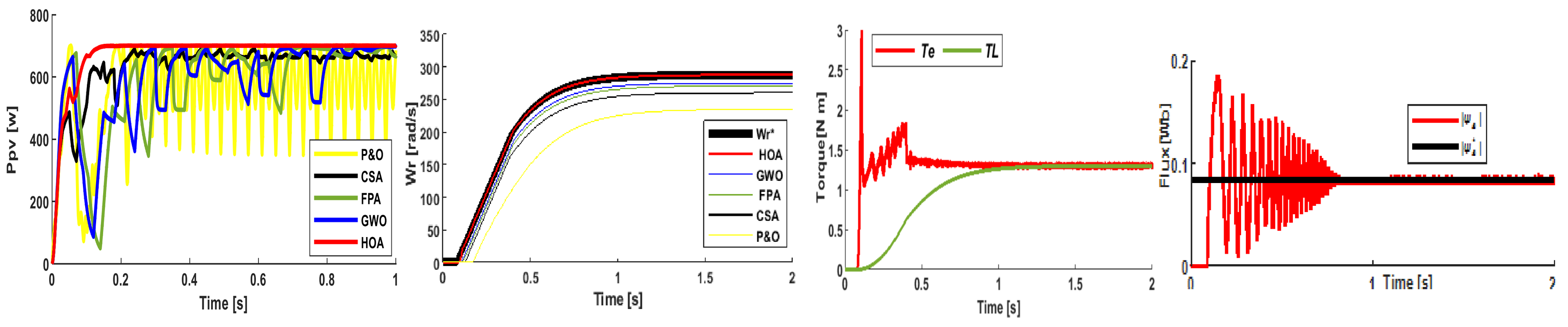


Fig. 3 Dynamic performance of PV array and IM motor-pump, of proposed system under constant solar radiation

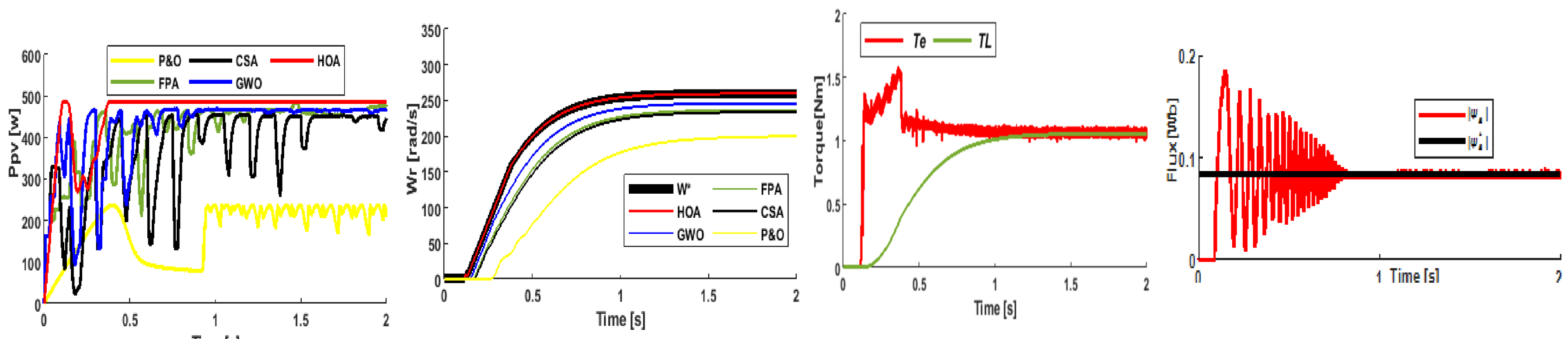


Fig. 4 Dynamic performance of PV array and IM motor-pump, of proposed system under under pattern 1

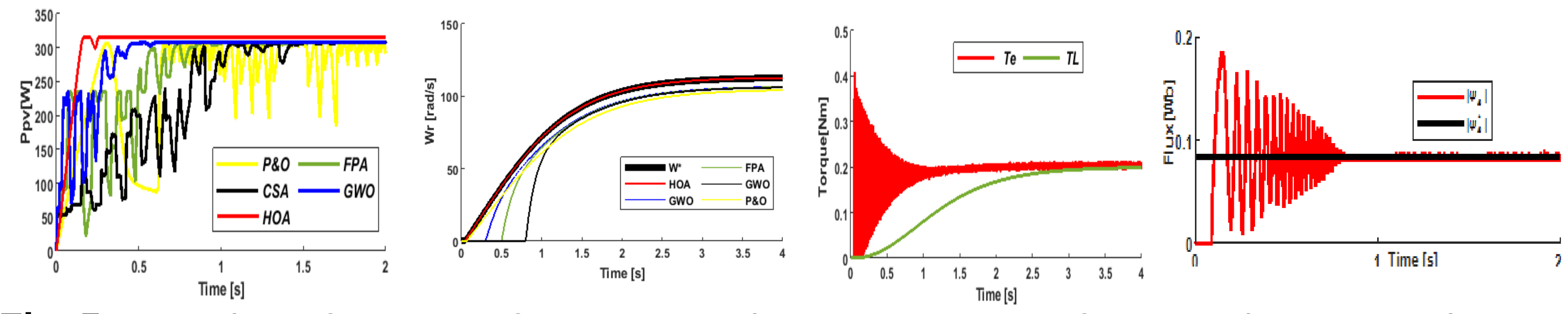


Fig. 5 Dynamic performance of PV array and IM motor-pump, of proposed system under under pattern 2

In the analysis, P&O , CSA , FPA , GWO , and Horse Herd Optimization Algorithm (HOA) MPPT methods were assessed under Standard Test Conditions (STC) and two distinct patterns (patterns 1 and 2), as illustrated in Figures 3, 4, and 5. Among these methods, HOA demonstrated superiority in extracting the Global Maximum Power Point (GMPP) efficiently without requiring significant time to converge to it

Fig. 6. provides a quantitative comparison of the water flow rate under different shading conditions between the HOA control and the previously mentioned MPPT methods

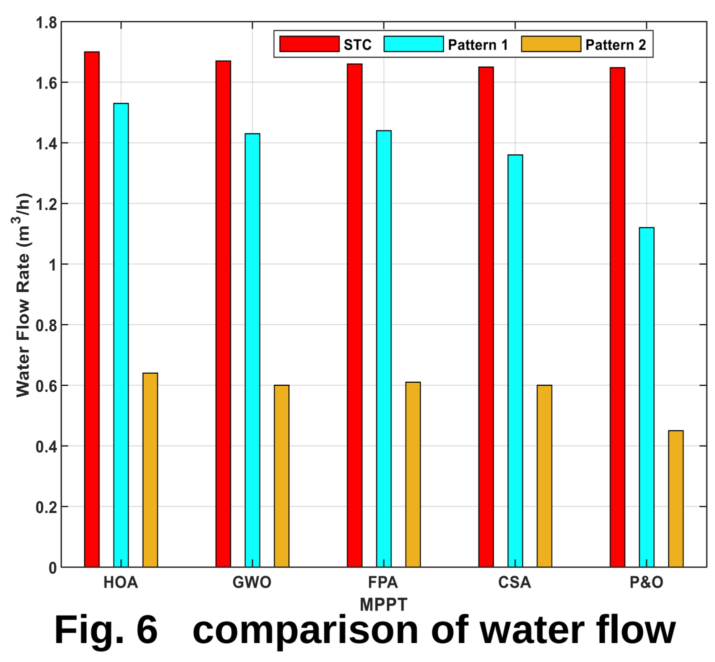


Fig. 6 comparison of water flow

CONCLUSION

This study introduces a standalone solar water pumping system powered by a low-voltage induction motor, designed specifically to operate effectively under partial shading conditions. Various MPPT algorithms, including Perturb and Observe (P&O), Cuckoo Search Algorithm (CSA), Flower Pollination Algorithm (FPA), Grey Wolf Optimizer (GWO), and Horse Herd Optimization Algorithm (HOA), were employed to accurately track the Maximum Power Point (MPP) under three Patterns. The analysis demonstrated the adaptability of the Horse Herd Optimization Algorithm to achieve the GMPP. Despite the inherent complexity of controlling a single-stage system due to the absence of a voltage boost feature in the voltage source inverter, Predictive Torque Control (PTC), ensures reliable and stable operation by effectively managing the inverter to achieve the desired reference speed, enhancing the system's performance. Ultimately, the combination of HOA-based MPPT and Predictive Torque Control exhibited promising performance, maintaining a high motor flow rate even under partial shading conditions.

FUTURE WORK / REFERENCES

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