S. No. - 13

# Final Report for Industrial Oriented Problem (EEN-300)

# SOLAR PV ARRAY FED INDIRECT VECTOR CONTROL OF INDUCTION MOTOR FOR PUMPING APPLICATIONS


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## 1. OBJECTIVE

The performance of Solar PV array fed Indirect Vector Controlled Induction Motor drive for centrifugal pumping application is analysed in MATLAB environment using Simulink and Sim Power System (SPS) toolboxes in Discrete Time Frame (DTF).

## 2. INTRODUCTION

Centrifugal pumps are the most preferred hydraulic pumps for industrial and domestic applications. It is used to transfer liquid from a lower suction tank to an upper receiver tank. Since efficiency of a centrifugal pump significantly depends on flow rate, it is required to control its rotating speed so that it can operate on a particular flow rate that corresponds to maximum efficiency region of pump characteristics. Rotor flux oriented indirect vector control of induction motor drive (VCIMD) scheme is used to control shaft speed so that we can have command on flow rate mismatch.

Vector control is a control technique through which the induction motor can be controlled to behave similar to a separately excited compensated dc motor. Decoupled components of the stator current space vector are taken as the control variables and are expressed in a 2-phase rotating frame of reference, which is aligned to either the stator mmf space vector or the rotor mmf space vector or the air gap mmf space vector, rotating with synchronous speed. The stator current will get split into two decoupled components one controls flux and the other control torque respectively. Henceforth such a control technique provides a substitute of separately excited compensated dc motor having fast torque and speed response.

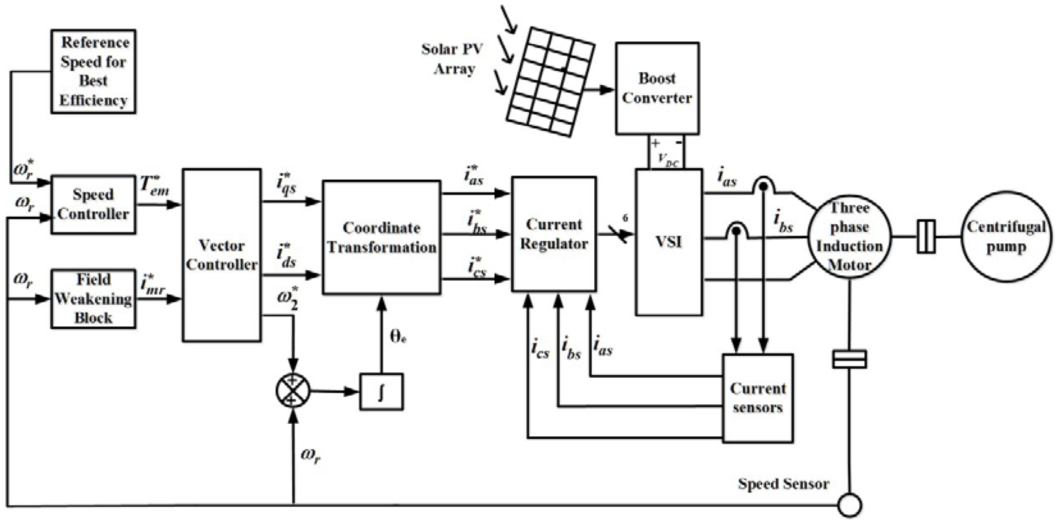


*Fig.1: Block diagram of Solar PV Array fed Vector Control of Induction Motor Drive for Pumping Application*

## 3. MPPT ALGORITHM

The Solar Photovoltaic (PV) array converts solar energy into electricity. Its power output depends on the incident Solar Irradiation and Temperature of cell. PV array can directly supply power to small loads at low efficiencies but for large electrical load we need to ensure that the power extracted from the PV array is maximum. This is done by operating the array at its maximum power point using a DC-DC Buck converter whose duty ratio is varied to vary the load seen by the PV array. We have employed Perturbation and Observation, a simple and effective method of Maximum Power Point Tracking.

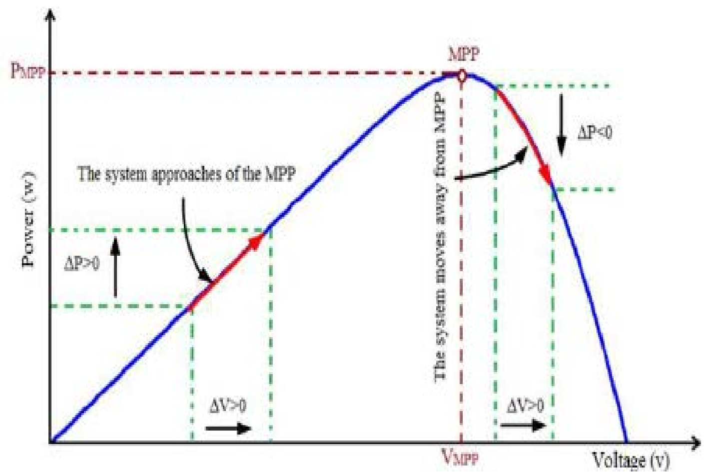


*Fig.2: P-V curve for the photovoltaic array*

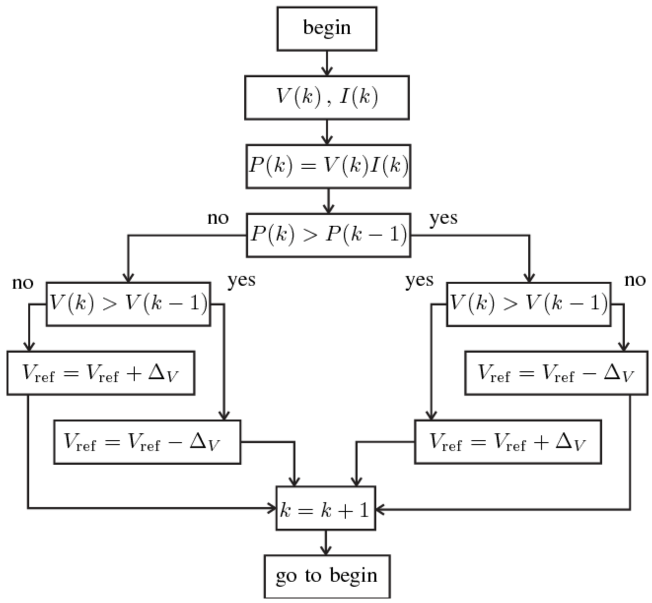


*Fig.3: Perturb & Observe MPPT Algorithm*

## 4. FIXED DC SUPPLY

The power output of PV array is increased to maximum value using MPPT algorithm. Due to this, the voltage output of Converter is a variable DC output which cannot be used to supply the Voltage Source Inverter. So, we have connected another DC-DC converter of Buck-Boost type to convert this variable DC supply into a Constant Voltage DC Supply which can be fed to VSI. The Buck Boost Converter is very efficient in maintaining fixed voltage whether its input voltage is greater than or less than the desired constant DC value.

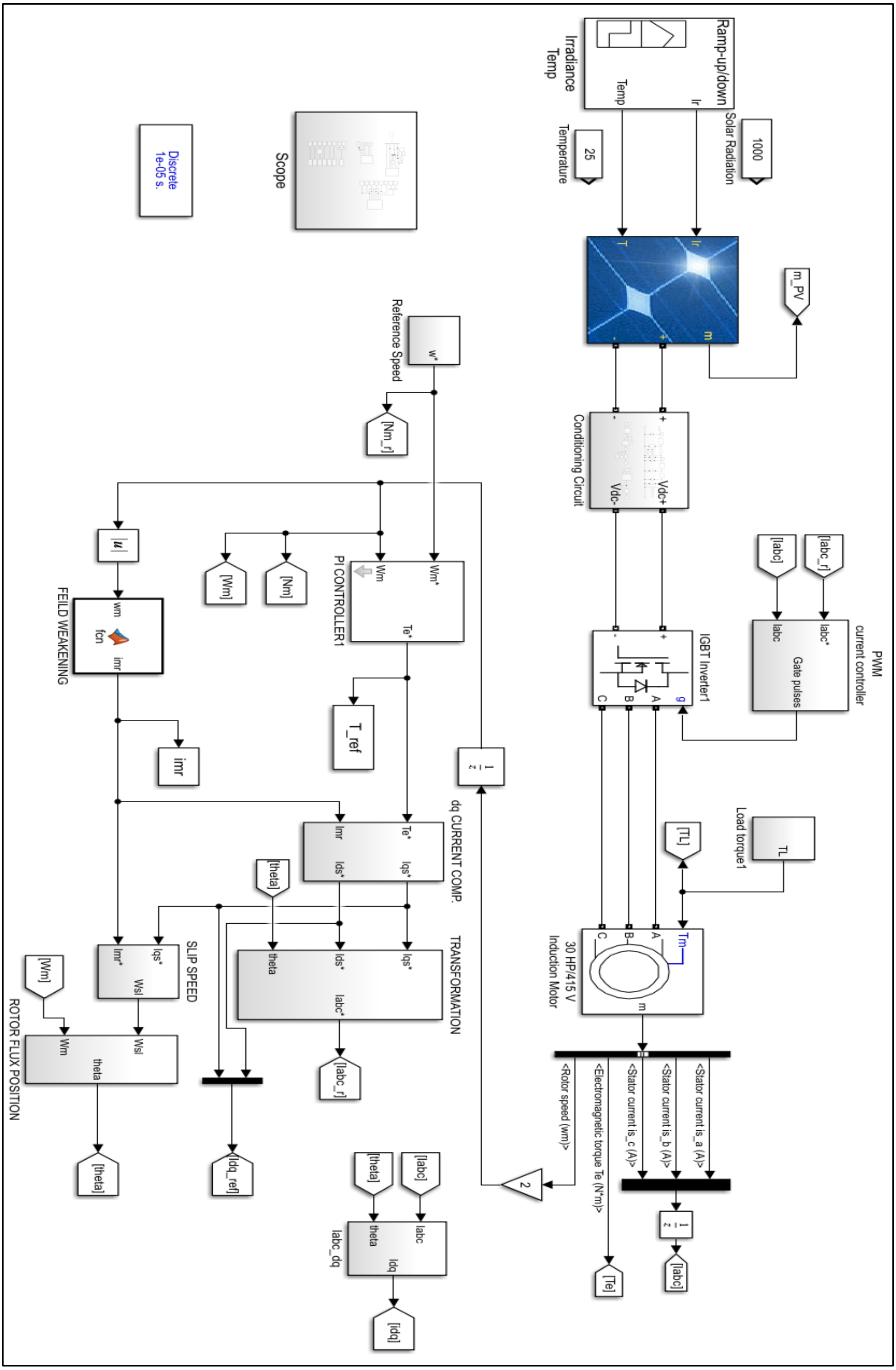


*Fig.4: MATLAB Simulation of solar PV array fed vector-controlled induction motor drive for centrifugal pump application.*

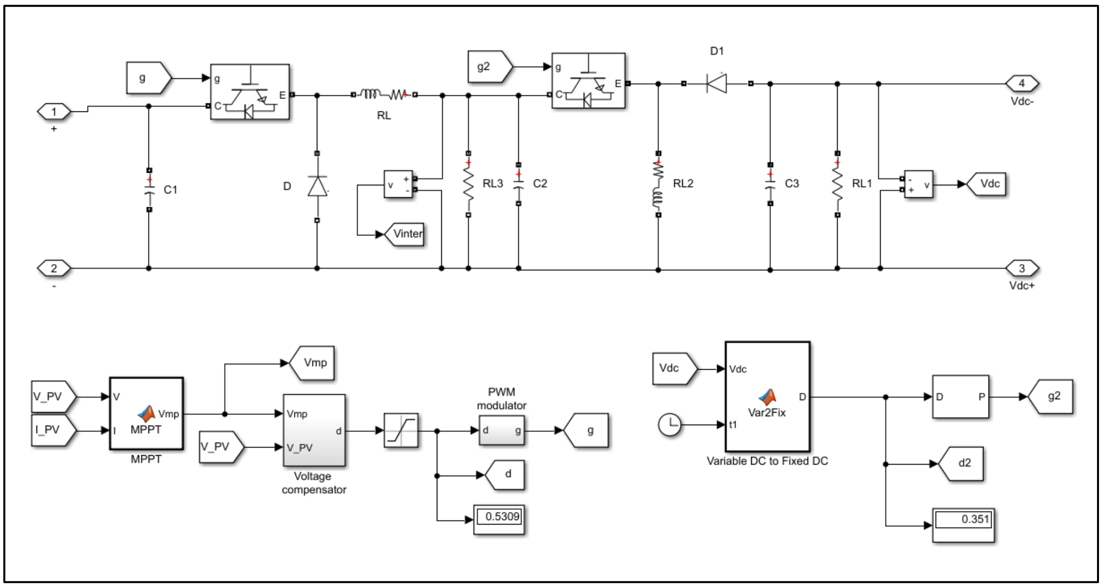


*Fig.5: Conditioning Circuit containing buck converter, buck-boost converter and their control circuits.*

```
function Vmp = MPPT(V, I)

persistent Vmp_old Pold Vold

if isempty(Vold)
    Vmp_old = 0;
    Pold = 0;
    Vold = 0;
end

deltaV = 0.1;

P = V * I;
dV = V - Vold;
dP = P - Pold;

if abs(dP) <= 100
    if (dP/dV) > 0
        Vmp = Vmp_old + deltaV;
    else
        Vmp = Vmp_old - deltaV;
    end
else
    Vmp = Vmp_old;
end

if Vmp >= 750 || Vmp <= 0
    Vmp = Vmp_old;
end

Vmp_old = Vmp;
Vold = V;
Pold = P;
```

*Fig.6: Code for MPPT algorithm*

```
function D = Var2Fix(Vdc, t1)

Vdc_ref = 560.45;

persistent Dold

if isempty(Dold)
    Dold = 0;
end

Dmax = 0.75; Dmin = 0.35;

deltaD = 1e-3;

if t1 < 0.5
    D = 0;
elseif t1 < 1.7
    D = 0.55*(t1-0.5);
else
    if Vdc < Vdc_ref
        D = Dold + deltaD;
    elseif Vdc > Vdc_ref
        D = Dold - deltaD;
    else
        D = Dold;
    end

    if D >= Dmax || D <= Dmin
        D=Dold;
    end
end

Dold = D;
```

*Fig.7: Code to calculate duty cycle for buck-boost converter*

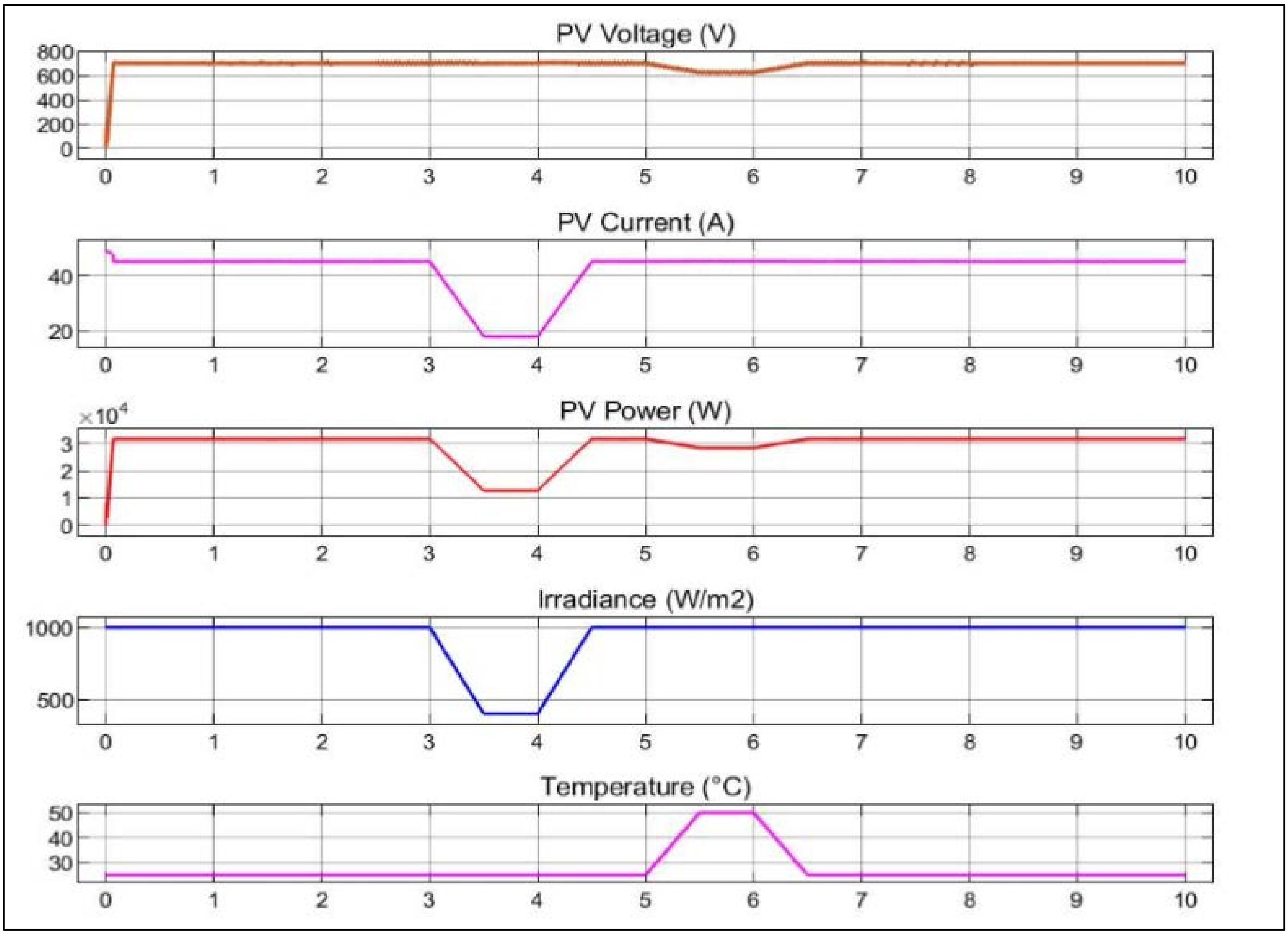


*Fig.8: PV Array waveforms*

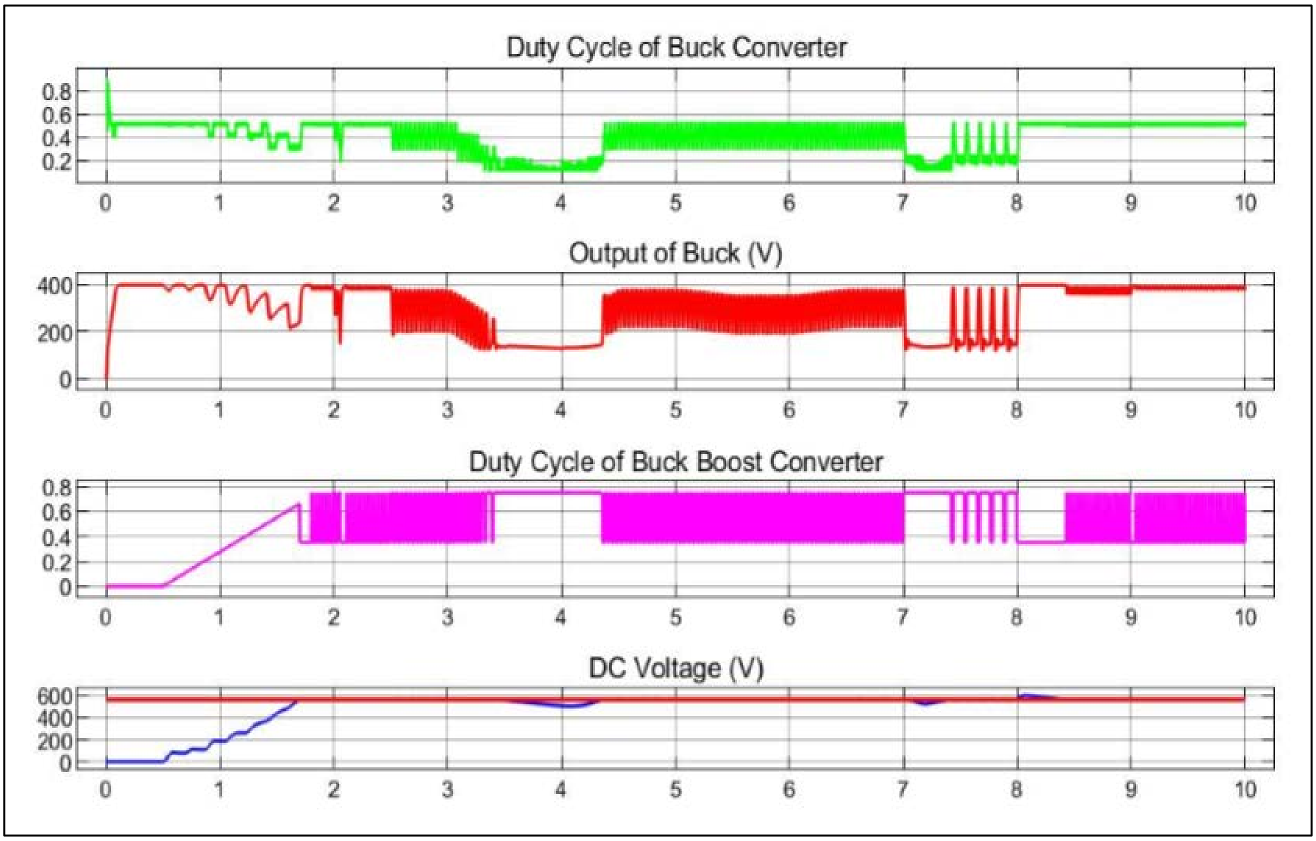


*Fig.9: DC-DC converters waveforms*

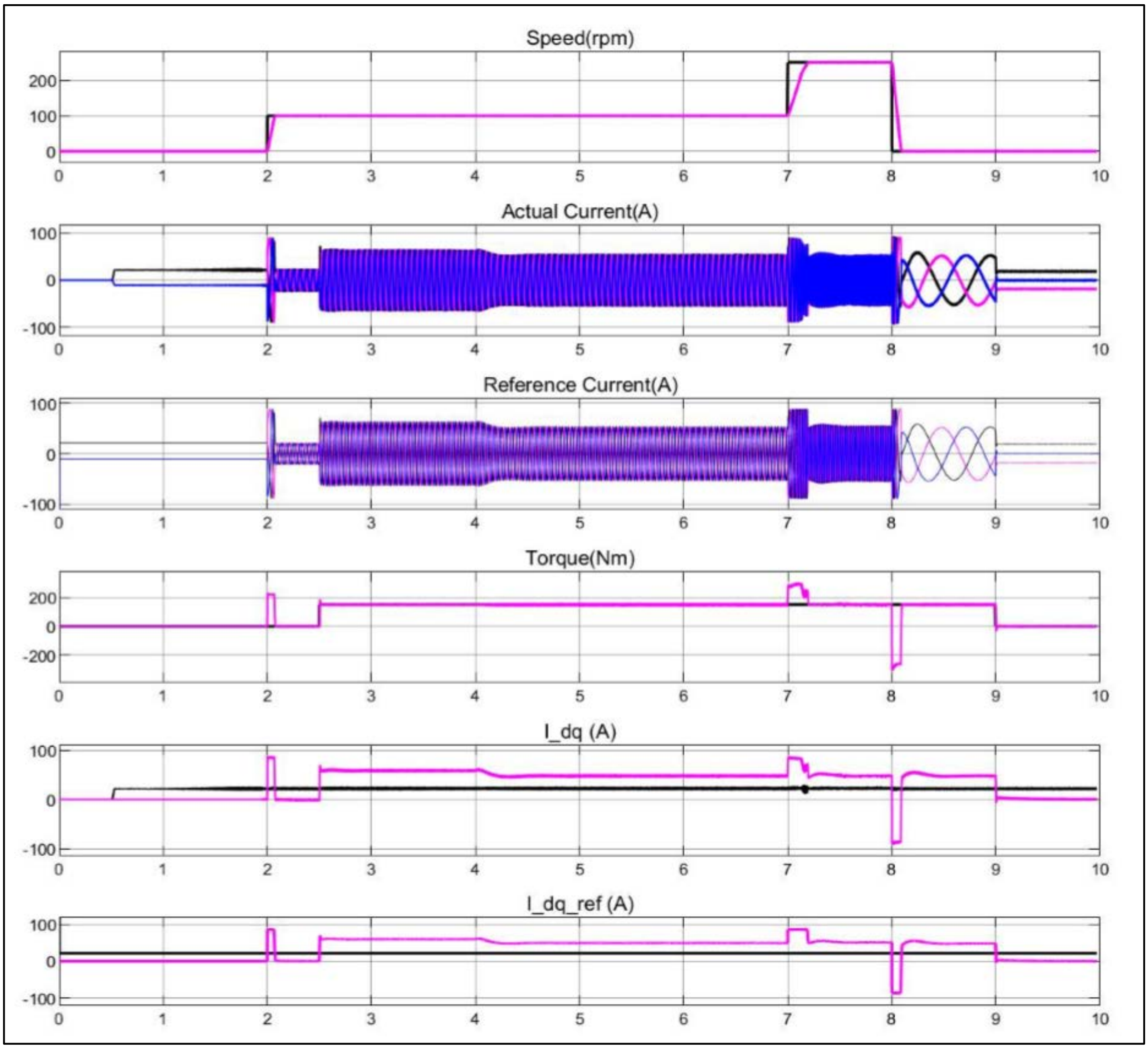


*Fig.10(a): Vector Controlled Induction Motor Waveforms*

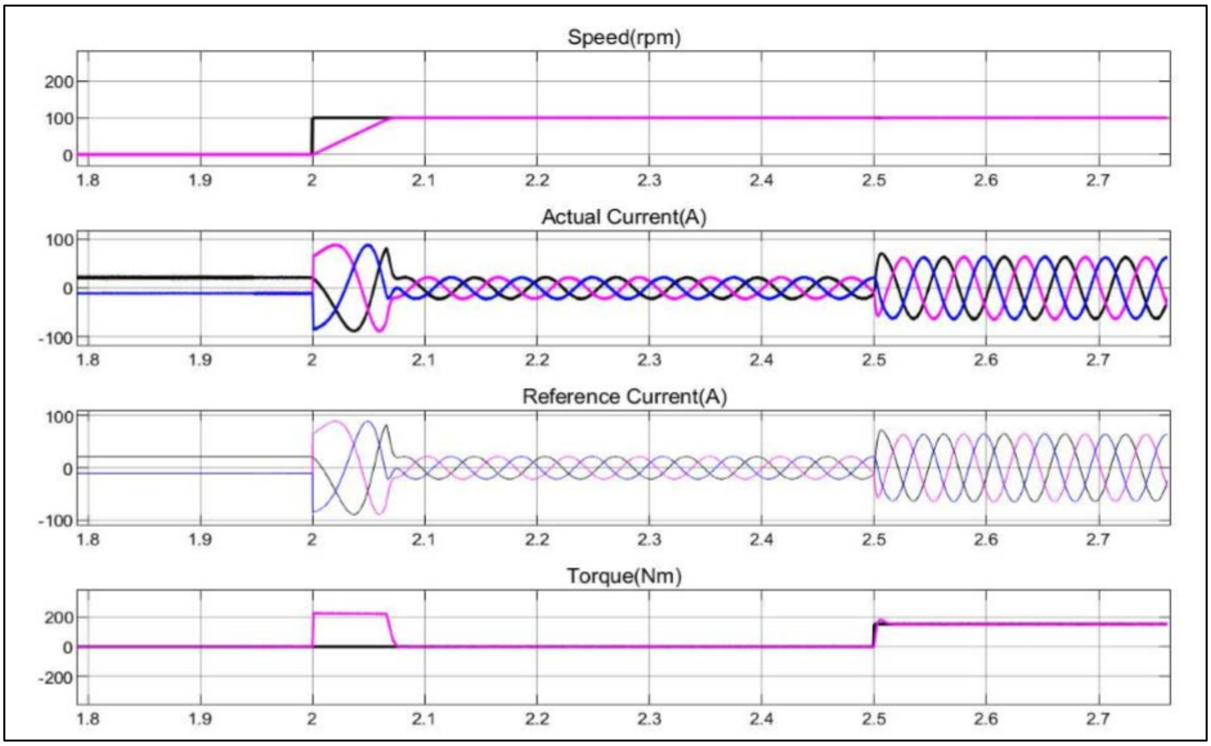


*Fig.10(b): Starting of induction motor*

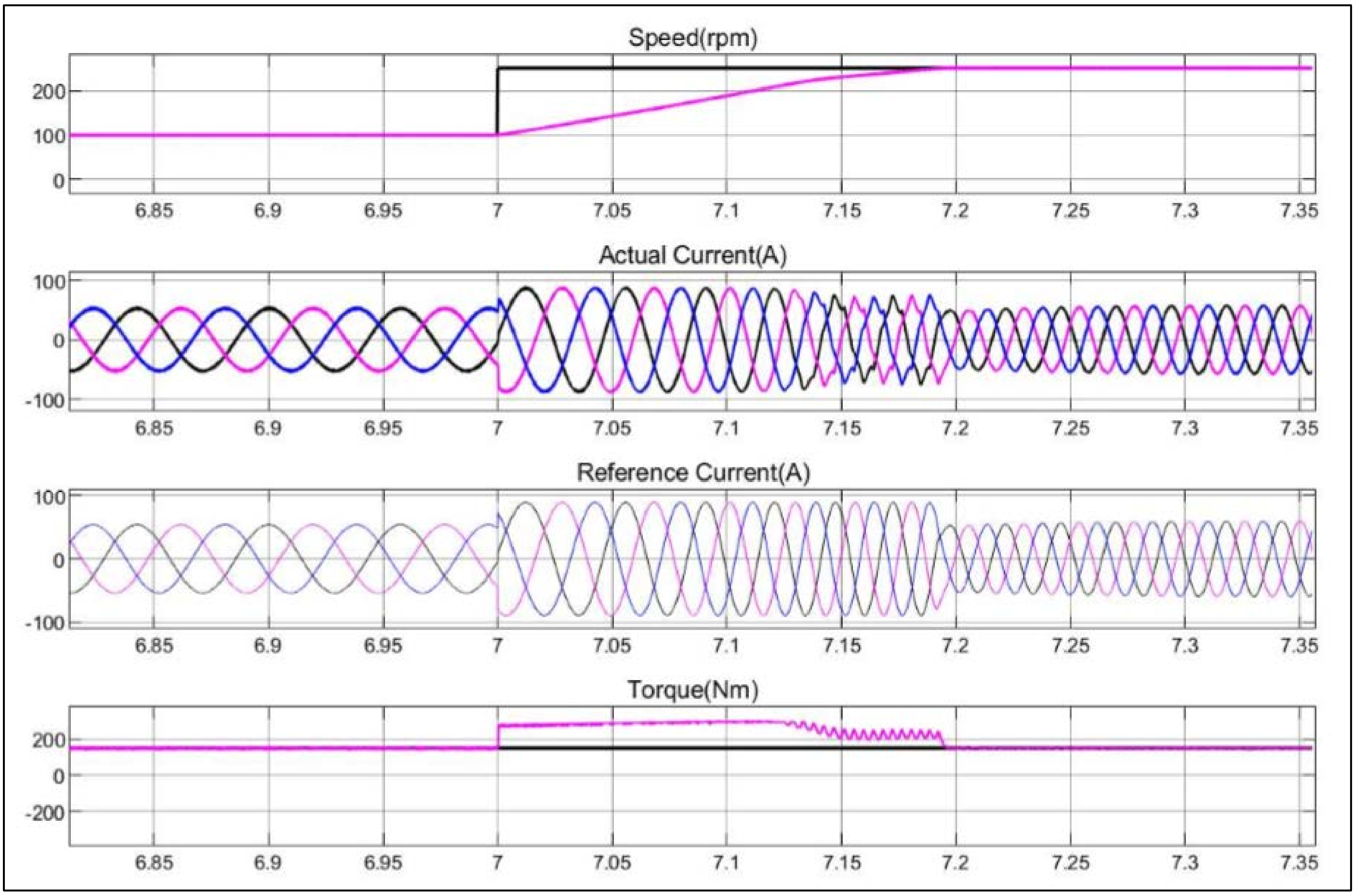


*Fig.10(c): Change in reference speed of induction motor*

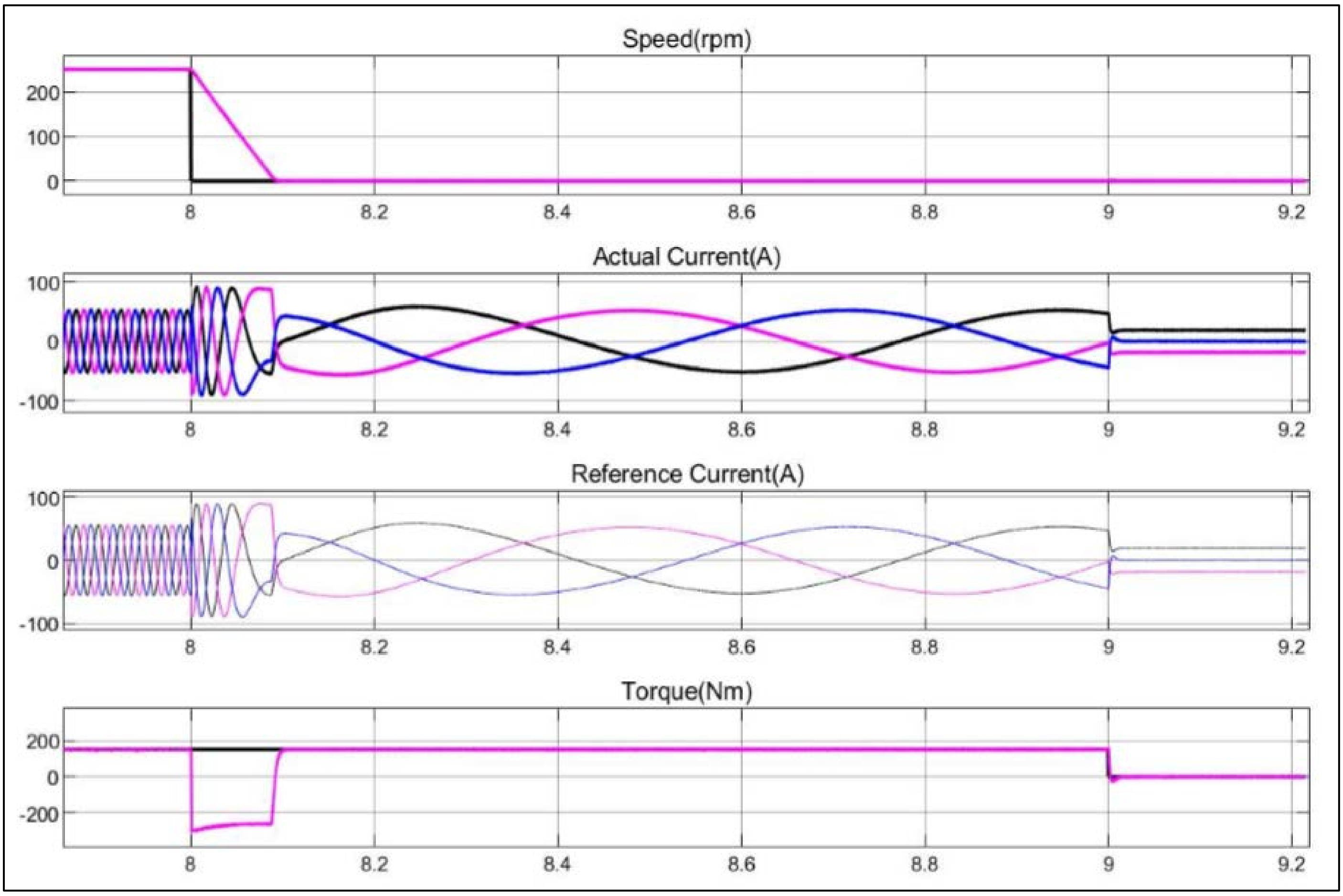


*Fig.10(d): Braking of induction motor*

## 5. WORK LEFT:

1. Mathematical Modelling of Centrifugal Pump and calculation of its maximum efficiency condition.
2. MATLAB Simulation of the same.
3. Analysis of the above model in real world Irradiation and temperature conditions.

## 6. REFERENCES:


1) J.M.D. Murphy and F.G. Turnbull, Power Electronic Control of AC Motors, Oxford, Pergamon Press, 1988 – Chapter 7.12 Field Oriented Control.

2) Villalva MG, Gazoli JR, Filho ER, Modelling and Circuit-Based Simulation of Photovoltaic Arrays. Power Electronics Conf., 2009, 1244-1254, 2009.

3) M. G. Villalva and E. R. F., “Analysis and simulation of the P&O MPPT algorithm using a linearized PV array model,” 2009 35th Annual Conference of IEEE Industrial Electronics, Porto, 2009, pp. 231-236.

4) Shukla, Saurabh & Singh, Bhim. (2018). Reduced Sensor Based PV Array Fed Direct Torque Control of Induction Motor Drive for Water Pumping. IEEE Transactions on Power Electronics. PP. 1-1. 10.1109/TPEL.2018.2868509.


## 7. APPENDIX:

**Cage Induction Motor**
30 Hp, 3-Phase, 4-Pole, Y-connected, 415V, 45.0A, 50Hz
Rs =0.25Ω, Rr=11.72Ω, Xls = 0.439Ω, Xlr = 0.439Ω, Xm = 13.085Ω, J=0.305Kg m2
Speed Controller Parameters: KP=9, KI=2.6

**PV Array**
Waaree Industries WSM-315 module, Vmp = 35V, Imp = 9A.
5 Strings, 20 series connected modules per string.

**DC-DC Converters**
RL = 5 mΩ & 0.01H, RL1 = 150 Ω, RL2 = 5 mΩ & 0.01H, RL3 = 5Ω, C1 = 1 mF, C2 = 5 mF, C3 = 50 mF.
PWM Switching frequency = 10kHz