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Modeling for Speed Control of Induction Motor in Subsea Applications

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Abstract: Oil/Gas offshore extraction involves long feeders being used to supply power to Induction motors. Modeling previously was done ignoring effects of long feeders and line parameters. We design a model considering Long feeder effects and use of inverter output filters. We considered Field oriented control technique. Due to subsea applications we implement control technique at stator side itself. Stator values are measured and then transformed from three phase to 2 phase values using Clarke transform blocks. Long feeder is modelled as a π-model equivalent considering lump parameters.LC filter is used at inverter output to improve output response. Transformed values are fed to the designed controller which again feeds signal to inverter via SVPWM. Simulation and experiments show that model can be effectively controlled from stator side, LC filter helps to obtain a near sinusoidal output response and also helps to reduce harmonics and dv/dt rising of output voltage.

Keywords: Induction Motor, Sensor Less Control, LC Filter.

I. INTRODUCTION

Recent developments in control strategies due to advancement of Power electronic devices have enabled use of adjustable speed drives in subsea applications. For minor offshore oil applications electrical submersible pumps are dipped deep into the sea as long as about 1-7 km.

Due to long feeder connections problems incur as a result of traveling wave phenomenon. Long feeders may also result in introduction of harmonics and change in output voltage. In high inertia motor dip in voltage also causes starting problems.

Conventionally analysis was mainly based on control algorithm ignoring long cable effects on motors. In this paper modelling is done considering long cable model and also use of filters is done in order to improve the Voltage output. Simulation is performed considering 1km of cable in MATLAB and results are analysed.

The paper is organised in following sections. Following Introduction Section I. Section II FOC control technique, Section III Long Cable model is developed. Section IV contains simulation model and in section V shows simulation results. Finally, conclusion is forms Section VI.

II. SENSORLESS VECTOR CONTROL

The field-oriented control consists of controlling the stator currents represented by a vector. This control is based on projections that transform a three-phase time and speed dependent system into a two coordinate (d and q frame) time invariant system. These transformations and projections lead to a structure similar to that of a DC machine control. FOC machines need two constants as input references: the torque component (aligned with the q coordinate) and the flux component (aligned with d coordinate).

The three-phase voltages, currents and fluxes of AC-motors can be analysed in terms of complex space vectors. If we take ia, ib, ic as instantaneous currents in the stator phases, then the stator current vector is defined as follow:

$$is = ia + ibe^{\frac{2j\pi}{3}} + ic^{\frac{4j\pi}{3}}$$

Where, (a, b, c) are the axes of three phase system. This current space vector represents the three-phase sinusoidal system. It needs to be transformed into a two-time invariant coordinate system. This transformation can be divided into two steps:

- (a, b, c) → (α, β) (the Clarke transformation), which gives outputs of two coordinate time variant system.
- (a, β) → (d, q) (the Park transformation), which gives outputs of two coordinate time invariant system.

$$isq = is\alpha sin\theta + is\beta cos\theta$$

$$isd = is\alpha cos\theta + is\beta sin\theta$$

Where θ $is\ flux\ position$

Hence control over motor can be performed by transforming stator values into dq components and controlling them, to indirectly control toque and flux and resulting speed.

Long Cable Model

Π- Model of Cable: The modelling of Long Cable first needs proper analysis of the cable for which frequency analysis can be reliably considered. R, L, C can be represented in lump form even in transient analysis [3]. This modelling technique is simple and does not reduce the accuracy, this model is sufficient to give accurate results on long motor cable terminations [4]. Therefore, in this paper, a π-network with lumped elements R, L and C was used to model the long motor cable and output filter. Figure 1 shows the long cable and filter π-network model of inverter IM drive system. The simulated long motor cable was a subsea umbilical, which was also a PWM special insulation.

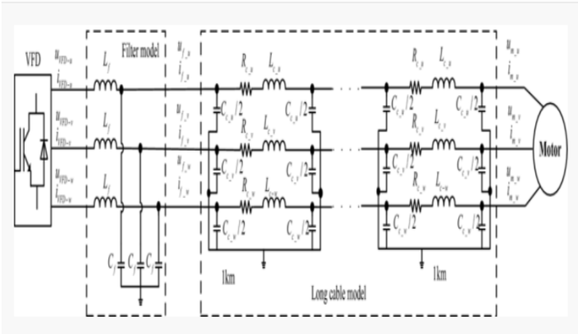


Fig 1. Feeder Model for a Subsea AC motor Drive Considering Π Model and LC Filter

III. INVERTER SIDE FILTERS

Passive filters are used to improve the voltage response.LC filters are chosen because it acts as overdamping circuit to overvoltage, reduces feeder harmonics, reduce harmonics in DC link current as RC filter is connected at motor side. Also, LC filers dissipate low power comparatively and hence need no coolers.[6]

While designing LC filter care is taken to keep time constant lower than critical time. [9]

$$\sqrt{L_F \times C_F} > T_{Critical}$$

$$T_{Critical} = 15 lc\Gamma \sqrt{L_c C_c}$$

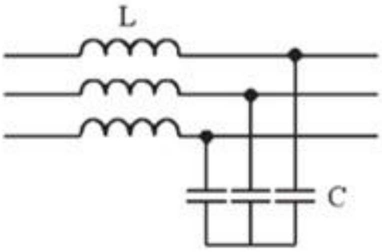


Fig 2. Proposed LC Filter

IV. SIMULATIONS AND EXPERIMENTAL RESULTS

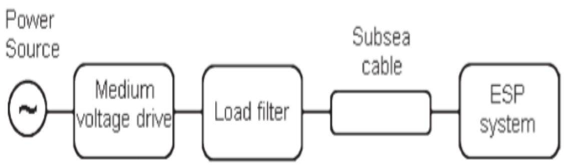


Fig. 3. Basic Block Diagram of SIMULINK Model

In this section we present simulation and results of the AC motor Drive. Model is simulated in MATLAB and behaviour of our model is investigated. Starting torque and Harmonics are investigated to obtain the performance efficiency of our model.

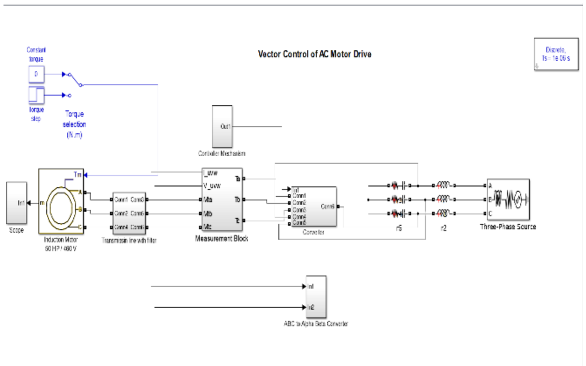
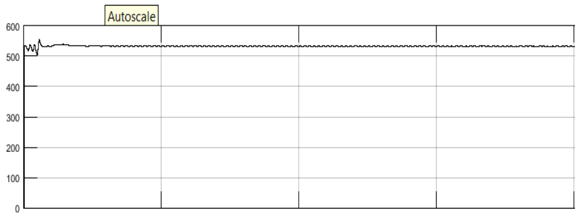
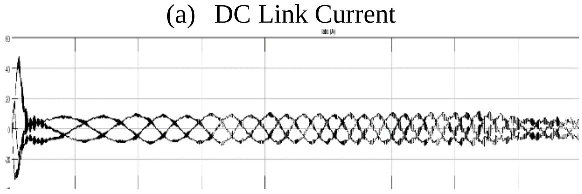


Fig. 4. Shows Simulink Model of Vector Control of AC Motor Drive

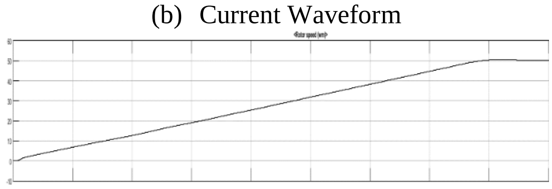
Three Phase AC source (380V rms) is used in combination with an IGBT diode based VSI inverter to drive the motor. Squirrel cage Induction motor (380V,50 Hz) is used. Motor has Rs = 2.71 Ω and Rr = 3.11 Ω, with Inertia of 0.3 Kg.m^2 and using 2 pole pairs. π-model of transmission line is assumed with R=0.34 Ω/km, L=0.29 mH/km and C=0.38 μF/km. Length of transmission line is 1 km. Inverter fed LC filters are also used, where L= 3 mH and C= 0.1 μF. PI controllers are used in control mechanism Kp= 18 and Ki = 200. Reference speed ω = 50 rad/flux reference (ϕ) = 0.9876 W and Torque (τ) is taken as zero. Using this setup, we perform Simulations and obtain the results i.e the waveforms of DC link current, Phase current, Torque. The waveforms are shown in following figures



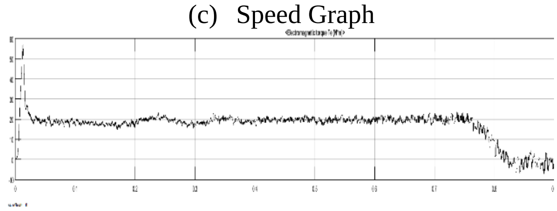
(a) DC Link Current



(b) Current Waveform



(c) Speed Graph



(d) Toque Graph

Fig. 5. (a). Udc shows the DC Link Current (b). Phase Current Waveforms (c). Speed Waveform (d). Torque Waveform

DC link current is almost a straight line with 540 as its value parallel to x-axis, initially starting torque and current is high and then it settles after starting of induction motor is achieved.

V. CONCLUSION

In this paper we proposed a model for VSI fed Induction motor drives. Model was able to track the given reference speed and with help of LC filters better response voltage was delivered. LC filters also reduced harmonic and due to making use of sensor less control, cost reduction and increased reliability and robustness can be achieved.

VI. REFERENCES

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