Simulation and Development of Automatic Excitation Control for Synchronous Motor

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Abstract— **Efficient usage of electrical has become a matter of focus nowadays not only in the industrial area but as well as in the area of agriculture. The synchronous motor is extensively used for the loads of constant speed, for the overall improvement of system power factor and sometimes for the voltage regulation also. In this paper, an automatic digital excitation controller with its control strategy is developed such that synchronous motor can operate over a wide range of power factors (lagging, unity or leading) by adjustment of its field excitation, and hence can be used to carry the mechanical load at constant speed and at the same time improve the power factor of the system. For that a typical test system is considered in which different cases such as open and closed loop configurations are analyzed by using software package PSIM 6.0. The proposed control is developed on the base of real time power factor detection.**

*Keywords—***Power Factor, Excitation Control, Control Card, Field Current**

I. INTRODUCTION

Synchronous Motors are widely used in power plant and industrial area to maintain the overall system power factor (p.f.) towards the unity. This is because of its one of the most important features that by changing the field excitation, it can be made to operate from lagging to leading power factor. it is concluded that if the synchronous motor is under-excited, it has a lagging power factor. As the excitation is increased, the power factor improves till it becomes unity at normal excitation. Under such conditions, the current drawn from the supply is minimum. If the excitation is further increased (i.e., over excitation), the motor power factor becomes leading. And consequently the armature current is minimum at unity p.f and increases as the power factor become poor, either leading or lagging.

R.C. Schaefer in [1] has discussed basic theory, operation, and control of synchronous motor. The author in the same

paper provides information concerning control and optimization of the motor through the use of power factor control and also describes the protection in brief.

M.M. Al-Hamrani et al in [2] confer about the practical method to optimize usage of synchronous machine in industries. The author, with an illustrative example, gave an outline about adaptive excitation control in which on tne base of real time feedback, the excitation is changed to bring the system to an optimal operating point.

II. SYSTEM DESCRIPTION

Fig.1 shown below is the general arrangement of an automatic excitation system of a synchronous motor.
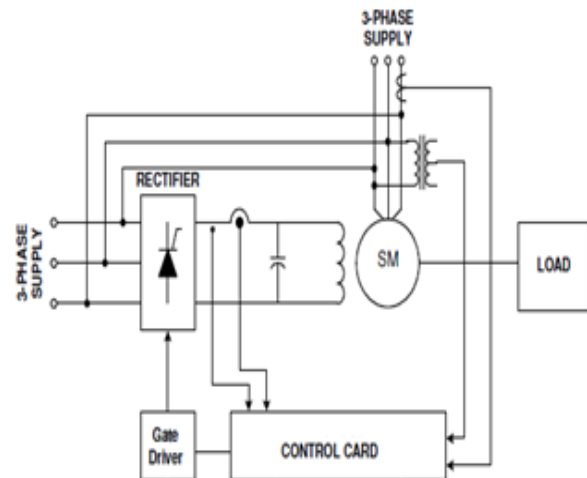

Fig.1 General Arrangement of test System

As shown in Fig.-1- a controlled rectifier is used to get the D.C. current, which is given to the field by changing the firing angle of SCR, the excitation current can be

changed. Power Factor is sensed by monitoring the voltage across motor's two phases and current from third phase. Then that feedback is given to a control card. In this card, set points of power factor as per requirement are programmed. So that as the load changes, the excitation requirement will also change automatically and power factor is maintain between entered set values.

Power factor is related to the phase angle between voltage and current. Synchronous motors seldom, if ever, operate continuously at lagging power factor. Synchronous motors run at either unity or some value of leading power factor. Lagging power factor appears when the motor load angle increases beyond rated, becoming almost fully lagging (90°) as the motor slips out-of-step. Motor Power factor during induction motor operation (that is with field removed) is always lagging. Therefore, lagging power factor can be utilized to initiate action to prevent slipping. Lagging power factor can again be utilized as an indicator of "slip" during induction motor operation. For synchronous motors, Power factor monitoring can be employed to guard against pull-out or loss of field conditions. Power factor is displayed with leading or lagging value on the LCD

III. SYSTEM OPERATION

In order to analyze the behavior of an automatic excitation, two cases have been considered which are as hereunder:

A. Open Loop Excitation Control
B. Closed Loop Excitation control

A. *Open Loop Excitation Control*

The algorithm depicted in Fig.2 has been developed to compute the system power factor from the real time voltage and current signals.

B. *Closed Loop Excitation Control*

In this configuration the real time system power factor is calculated in the same manner as in open loop configuration but the algorithm of the control card will decide a particular firing angle such that the motor will operate at pre-set value of power factor. Here, the actual power factor is taken as a feedback. By giving the reference power factor to the error detector difference is generated. Based on that firing angle will be set and according to that field current will also set and maintain

the constant Power factor. Once the desired power factor will enter then even if the load is change then also set power factor will maintain synchronous speed.
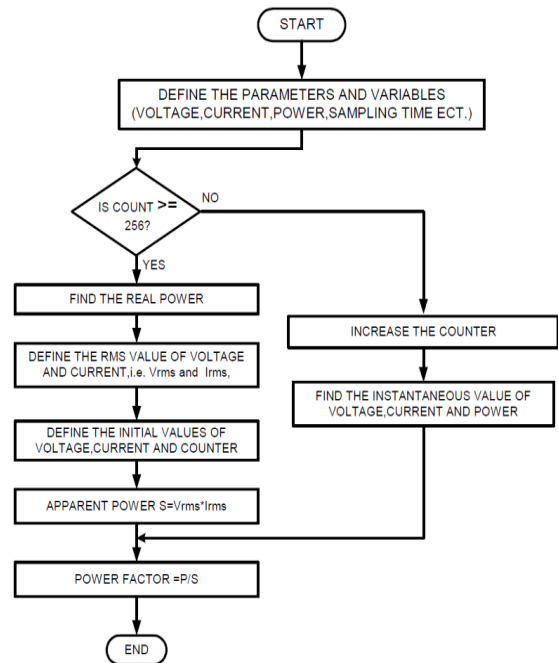

Fig.2 Flowchart of Power Factor Computation
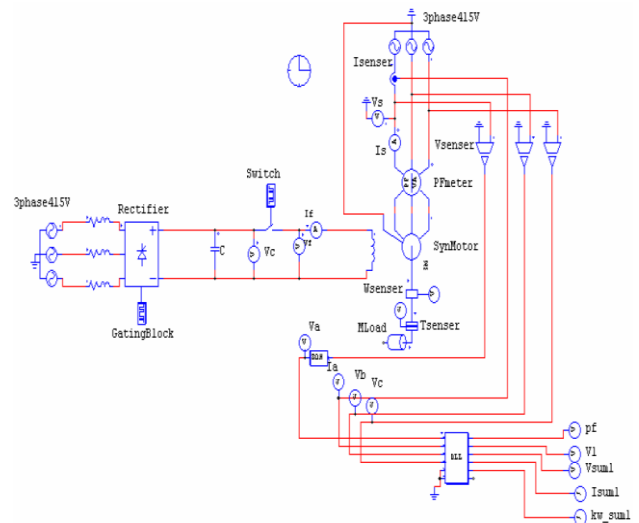
IV. SIMULATION & RESULTS

Fig.-3 Open Loop Excitation System

As shown in Fig.3 one switch is kept between the rectifier output and the field. Because DC supply is applied when the synchronous motor will reach 95% of the rated speed. Power factor is measured by using the power factor meter. Power factor of the DLL output is compared with the actual power factor, which both are similar. Simulation is carried out with under excitation and over excitation dc field voltage. Excitation requirement can be change by using the firing pulses.

Results of field current, field voltage, power factor (Actual and programmed) are given in the table-1 for open loop simulation.

TABLE-1
RESULTS OF OPEN LOOP SIMULATION

Sr. No.	Firing Angle (α°)	Field Current (amp)	Field Voltage (volt)	Actual Power Factor	DLL Power Factor	Status
1.	120	58	40	0.47	0.47	Lagging
2.	105	160	112	0.70	0.70	Lagging
3.	90	278	195	1.0	1.0	Unity
4.	75	398	279	0.69	0.69	Leading
5.	60	487	342	0.51	0.51	Leading

So here from the result table 1, at the different firing angle PF variation range for synchronous motor operation is decided.

Now in close loop configuration as shown in fig-4, by taking the values of the different power factor (Reference) simulation is carried out. For particular reference power factor corresponding waveforms of actual power factor (PFmeter), DLL output power factor (PF), Stator current and voltage, field current(If), field voltage (Vf) for lagging and unity power factor cases are as in fig.-5(a) to (f).

Here from the Close Loop simulation table at different reference power factor firing angle and field current is changed automatically even though motor speed is constant.
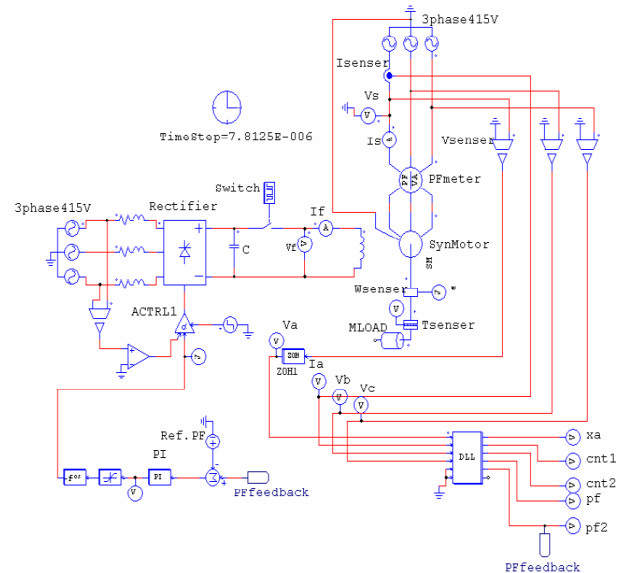

Fig.4 Closed Loop Excitation System

Results of field current, field voltage, power factor (Actual and programmed) are given in the table-2 for close loop simulation.

TABLE-2
RESULTS OF CLOSE LOOP SIMULATION

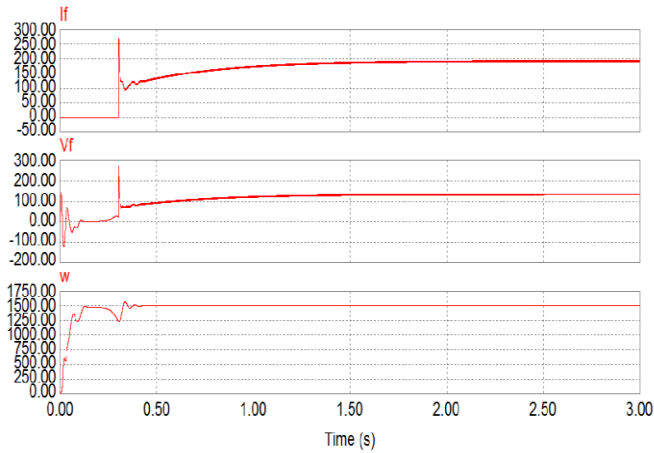| Sr. No.	Ref.PF (Set PF)	Field Current (amp)	Field Voltage (volt)	DLL PF (Calculated PF)	Actual Power Factor
1.	.65 lag.	144	108	0.65	0.65
2.	.75 lag.	177	126	0.75	0.75
3.	.85 lag.	208	145	0.85	0.85
4.	.95 lag.	234	165	0.95	0.95
5.	1 Unity	260	181	1.0	1.0
6.	.95 lead	309	215	0.95	0.95
7.	.85 lead	347	242	0.85	0.85
8.	.75 lead	380	265	0.75	0.75
9.	.65 lead	416	291	0.65	0.65

Fig.5(a) Field Current, Field Voltage & Speed at 0.8 lag.P.F.
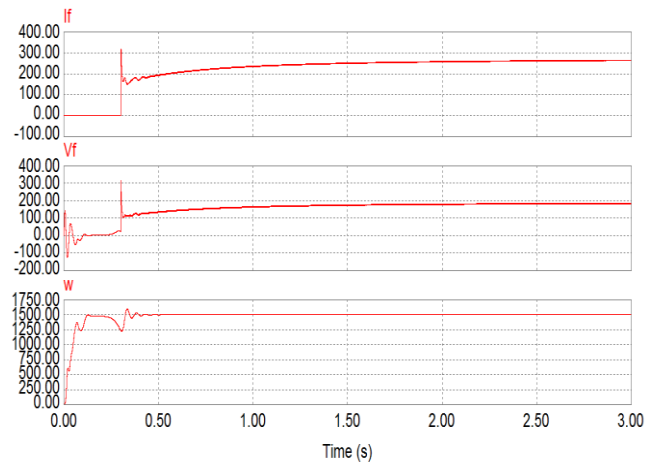

Fig.5(d) Field Current, Field Voltage & Speed at unity P.F.
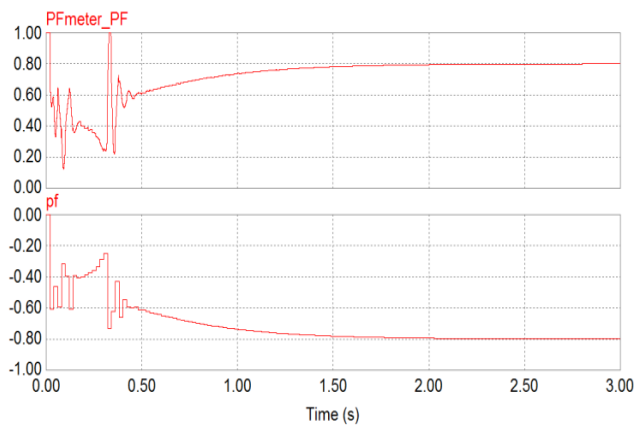

Fig.5(b) Actual and Programmed Power Factor at 0.8lag P.F.
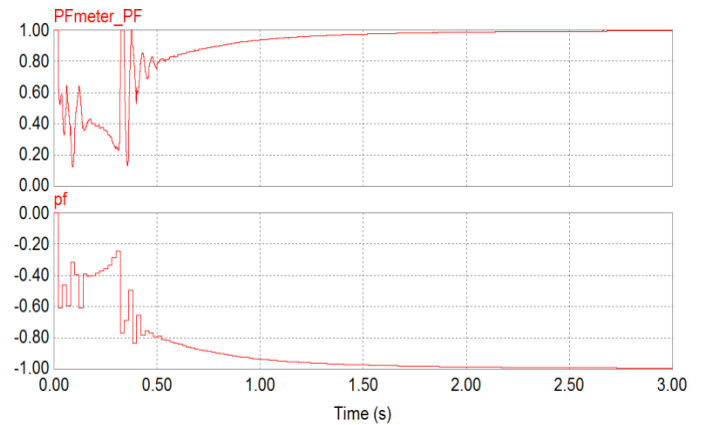

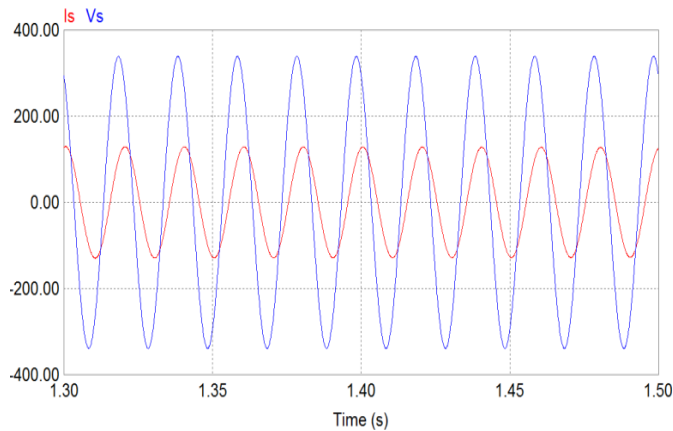Fig.5(e) Actual and Programmed Power Factor at unity P.F.

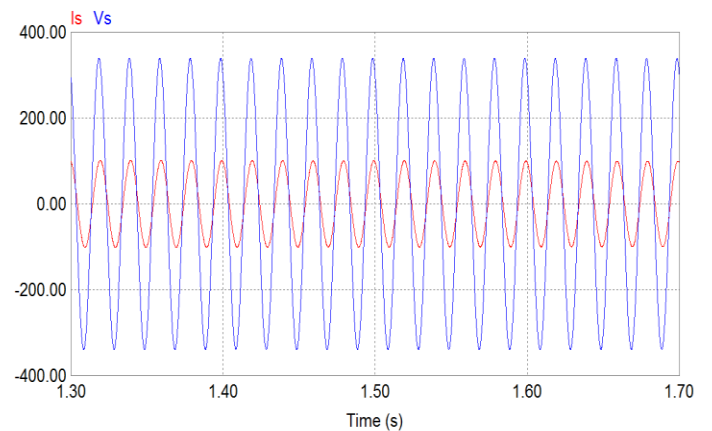Fig.5(c) Stator Current and Stator voltage at 0.8 lag.P.F.

Fig.5(f) Stator Current and Stator voltage at unity P.F.

V. CONCLUSION

From simulation results by changing the firing angle of the rectifier the excitation current, voltage and power factor would be change In open loop and close loop system Calculated (DLL output PF) power factor and actual (System) power factor is compared and both are same. From close loop simulation it is observed that if ref PF is change then firing angle is changed automatically. By giving the desired power factor as a reference the firing angle will change automatically and set the necessary field current and maintain the constant power factor. Selecting the appropriate excitation system depends on the field current required for the motor field. Finally from the simulation results the power factor of the motor can be change within certain range and motor is operated at unity or leading power factor as per requirement.

VI. REFERENCES

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