A comparative study of Capacitor Phase Splitter for the Operation of Irrigation Pump Motors

Mallikarjun.G. Hudedmani[1] Iranna. Hiremath[2] Shrithi Yaligar[3] Arshadaunnisa banu S[4] Meghna P[5]
[1]Associate Professor
[1,2,3,4,5]Department of Electrical and Electronics Engineering
[1,2,3,4,5]KLE Institute of Technology, Opposite to Airport, Gokul, Hubballi, Karnataka, India

Abstract— Agriculture is backbone of India, where irrigated agriculture sector plays an important role in its economic development and poverty alleviation. Near about 70-75% of population in India is dependent on agriculture for its livelihood. Agriculture contributes about 16% of total GDP and 10% of total exports. Irrigation is the base for about 56% of total agricultural output. Recognizing the importance of irrigation as a crucial input in India's agricultural development harnessing of water resources for irrigation through motor pumps is necessary. Irrigation in India is carried by various types of systems such as wells, tanks, perennial canal, multipurpose river valley projects, inundation etc. Running 3 phase pump on single phase supply leads to unbalanced condition in the system that leads to various negative effects such as overheating, insulation degradation, line current unbalance, torque pulsation, de rating and inefficiency. In spite of these adverse effects on motor and irrigation feeder, it is observed that farmers run their 3 phase motor on single phase supply and under reduced voltage condition using capacitor splitter. A case study of capacitor based phase splitter (single phase supply mode) is implemented on work bench and compared the performance after simulating the similar in MATLAB/SIMULINK. As a extension of work a comparative study of operation of pump motor for balanced and unbalanced supply condition is also done.

Key words: Induction motor simulation, Capacitor phase splitter, Effects of single phase operation, Performance of motor

I. INTRODUCTION

India is mainly an agricultural country and agriculture has been a source of livelihood for more than 2/3rd of our population. As agriculture, horticulture, sericulture mainly depends on continuous water supply and farmers depend on seasonal rainfall for supply of water for proper cultivation. Hence it is necessary to opt for artificial application of water (Irrigation) using electrical motors and pumps for the continuous water supply. Irrigation is the base for about 56% of total agricultural output. India has an irrigation potential of about 139.89 million hectares and out of which only 40% is cultivated area, which benefited from the irrigation projects. Recognizing the importance of irrigation as a crucial input in India's agricultural development harnessing of water resources for irrigation through motor pumps is very necessary. Pumping the water for the irrigation needs pump as basic component driven by a suitable prime mover and to provide sufficient pressure and required flow rate. Pump's performance in the irrigation system is dependent on the parameters such as capacity, head (H), discharge (Q), power, efficiency, required net positive suction head and specific speed. The flow rate required by the irrigation system depends on the size and type of the irrigation system, water requirement, time and duration of operation and efficiency of the system pumps. Various types of pumps used are namely, centrifugal, submersible, Inline, end suction, multi stage jet etc.

AC Motors are playing a very vital role in irrigation pumping applications. Electromagnetic induction and dynamic force action is the principle of operation of motors. Rotating field is created in 3 phase motor and they are self starting unlike single phase motors. The main reason for their choice is their flexibility and huge variety which can match almost any kind of demand. Generally, any pump which is used to irrigate the field is coupled to an induction motor designed to operate on three-phase power supply. Most rural lines are single phase as three-phase service normally requires a greater investment in transformers and lines which is not profitable. It is due to the fact most of the farms have higher annual energy consumption and poor load factor. 2

II. Literature survey

The literature survey has shown that water is the basic need for the agriculture. Agriculture is the largest consumers of water approximately 70% of the water we draw from rivers and underground sources [1]. Electrical motors used for pumps can provide years of trouble free service for long duration, low maintenance cost, dependability and ease of control when properly selected, operated and maintained. Most of the large electric motors used for irrigation are squirrel cage, 3phase, 440V Induction motors because of their easy maintenance, low cost and simple construction [2]. Three-phase service requires additional conductors compared to single-phase service and requires different metering equipment as well. As an alternative to utility installed three-phase supply power electronic devices like, rotary phase converters, static phase converters and variable frequency drives (VFD) have been used for decades to generate three-phase power from available single-phase source[3-5]. Also it is noticed that working of 3 phase induction motor fed by single phase supply using convertors lead to severe ill effects on Induction motors and that affect the power grid and damages the equipment [4-7]. The centrifugal pump or Submersible pumps are the machines most commonly used to move liquids from one place to another [8-9]. The computer simulation software such as MATLAB/SIMULINK provides the environment to simulate and analyze the performance of a three phase induction motor for the wide variety of imposed constraints. These simulations provide step by step results and parameters for the comparative discussions [10-13].

III. SIMULATION OF INDUCTION MOTORS USED FOR IRRIGATION

Simulation is very necessary to justify the choice of motor and source available for judicious use of water to get adequate performance of motor. To evaluate and measure, an analysis is required in view of power consumption discharge, cost and maintenance. Operation of three-phase induction motor under balanced and unbalanced (single phase supply) conditions is carried out in MATLAB/SIMULINK version 2009b software. Also the capacitor phase splitter concept is demonstrated on the work bench for the comparative study. The simulation setup in MATLAB/SIMULINK uses the induction motor having the rating 3 phase, 415V, 50Hz, 7.5A, 1500rpm, 3.7KW/ 5Hp, efficiency of 85%. Various simulations are carried out and important parameters are tabulated for the study.

A. Simulation of Capacitor Phase Splitter for 3 Phase Induction Motor:

Figure 1 shows SIMULINK model of capacitor phase splitter. This model consists of Asynchronous machine, run capacitor C1 and start capacitor C2, two single phase voltage sources (A1, A3).

Motor rating= 415V, 50Hz, 7.5A, 1500rpm ,3.7KW/ 5Hp, efficiency of 85%, Capacitor 1, C1= 72µfd and Capacitor 2, C2= 50µfd. Three phase V-I measurement block, Three phase active and reactive power measurement block , sequence analyzer blocks, source impedance block, load, breaker , breaker control, display block and scopes. Three phase motor runs on three phase supply but when phase outage occurs only two phases are available to the motor hence capacitors are used to create artificial phase. Start capacitor C2 is used to start the motor and is disconnected from the system as the motor starts to run.

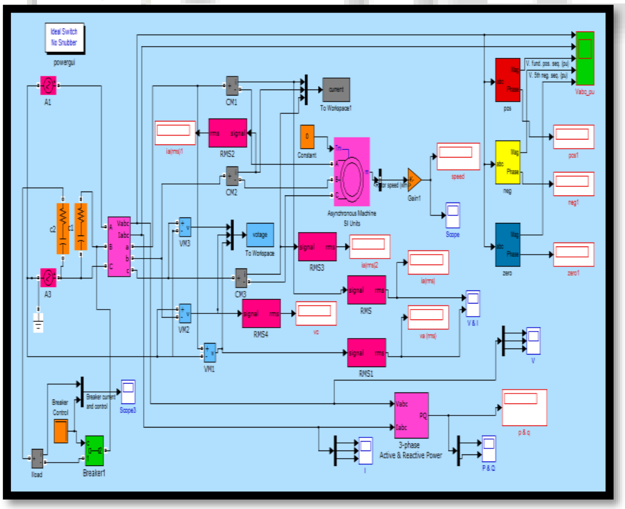

Fig. 1: Simulation of Capacitor phase splitter for 3 phase induction motor

Hence breaker is used to disconnect the start capacitor. Three phase VI measurement is used to measure the instantaneous voltage and current. Magnitudes and phase angle of positive, negative and zero sequence of voltage and current is measured using sequence analyzer block. The source voltage, source current, speed of the motor, real and reactive power flow obtained after the simulation are shown in the table

SL NO	Simulation Results (Capacitor phase splitter)					
	V_a (V)	V_b (V)	V_c (V)	I (A)	Speed (rpm)	Tm (N-m)
1	250	0	250	5.276	1475	0
2	250	0	250	10.56	1445	10

Table 1: Simulation results of capacitor phase splitter

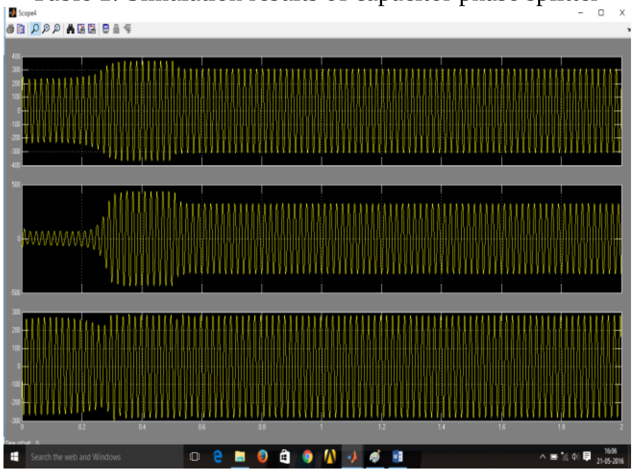

Fig. 2: Input voltage

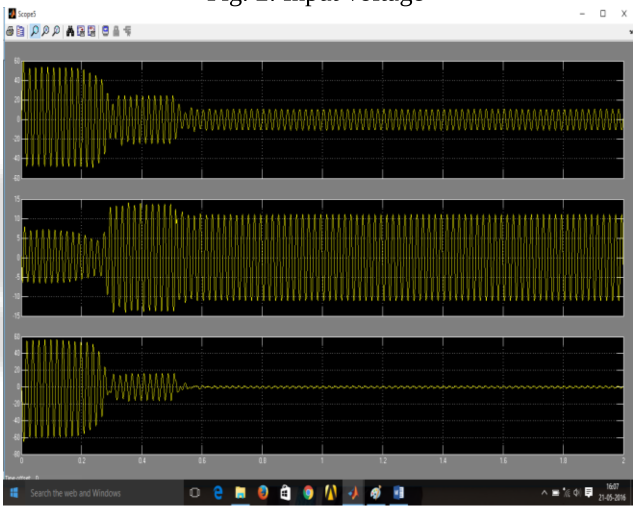

Fig. 3: Current

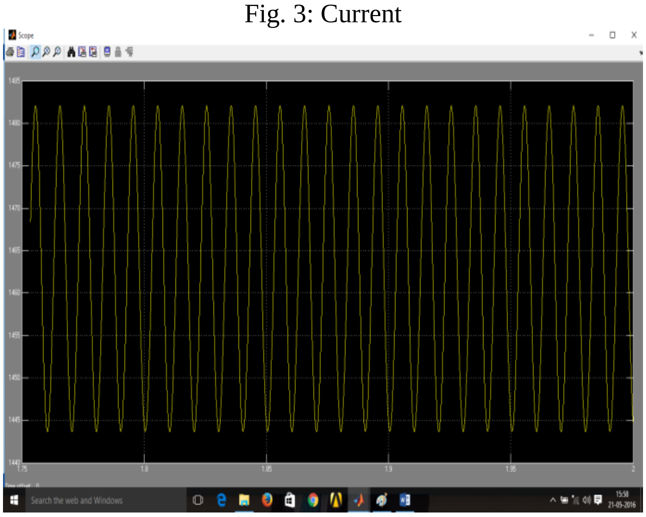

Fig. 4: Shaft Speed

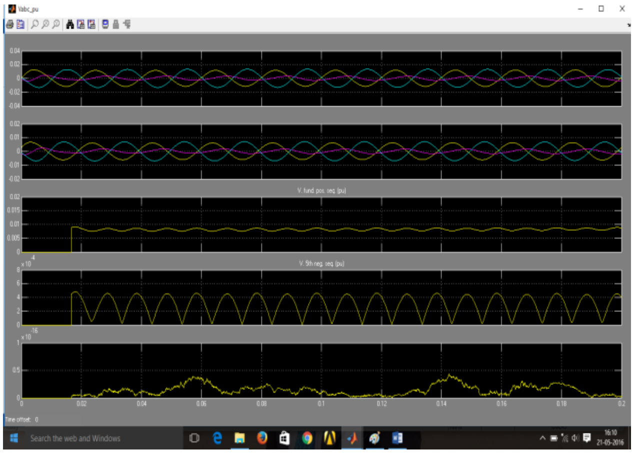

Fig. 5: Sequence analyzer wave forms

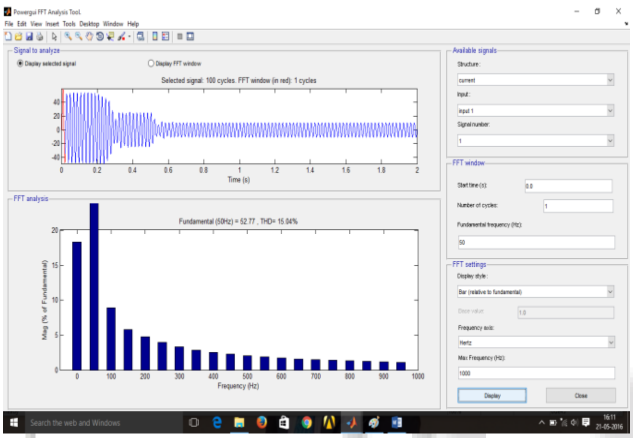

Fig. 6: THD in current signal in phase 1

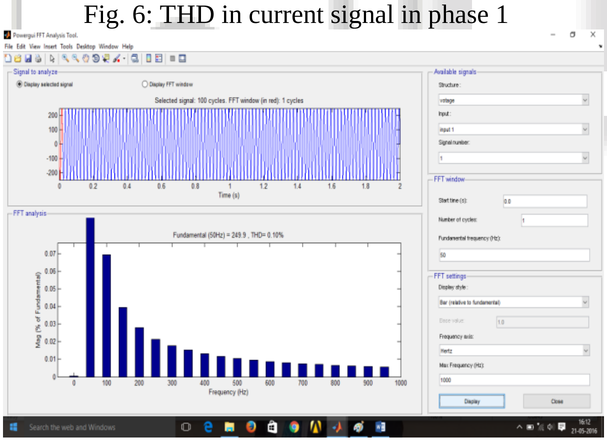

Fig. 7: THD in voltage signal in phase 1

B. Experimental Demonstration of Capacitor Phase Splitter for Three Phase Induction Motor and Comparison with Simulated Results:

Practical implementation of capacitor phase splitter is worked out with reference to circuit shown in the Fig 8 and is conducted on work bench. Readings of voltage, current and power are recorded from the set up for study and analysis. The impact of imbalanced mode using capacitor phase splitter is noticed. It causes absorption of higher current on lesser loads leading to effects such as insulation degradation, overheating, reduced efficiency etc leading to the failure of motor and capacitor degradation is observed. The de rating of motors on capacitor splitter is approximately 30% of name plate capacity.

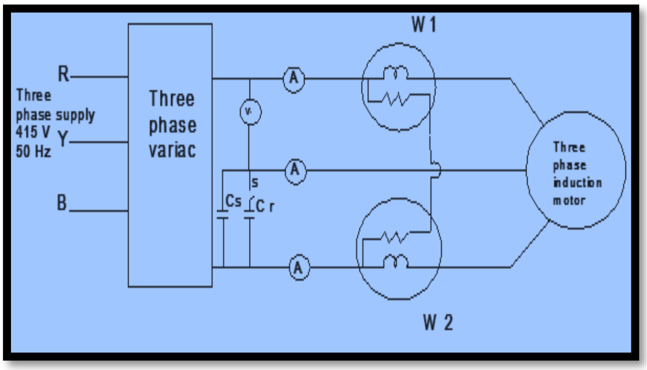

Fig. 8: Circuit diagram for capacitor phase splitter for 3 phase induction motor

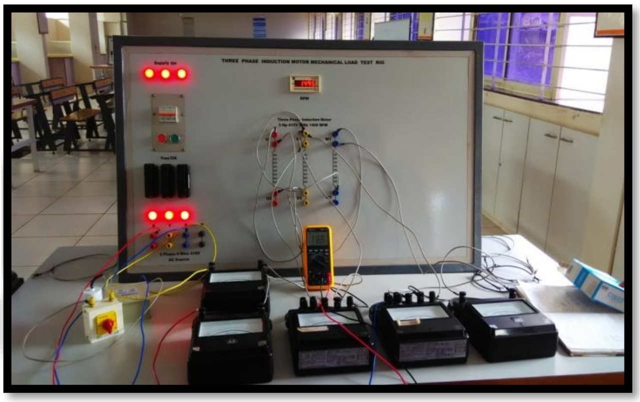

Fig. 9: Photographic view of capacitor phase splitter for 3 phase induction motor

List of equipments used are Start Capacitor: 50 µF, Run Capacitor: 72µF, Switch: 415V, 15 A SPS, Voltmeter: 600 volts, Ammeter: 0-15 amps, Motor: 3.7KW/5HP, Delta connected 3 phase induction motor. The set up includes the above equipments to run on two phase supply which is done by farmers. From this set up voltage, current and power are recorded on different loads of motor. It is noticed that motor absorbs high current and imbalances the motor operation. This practically justifies the de rating of motor.

SL No	Input Voltage			Simulation Results			Practical Results			Load (kg)
	V_a	V_b	V_c	I_a	I_b	I_c	Ia	Ib	Ic	
1	250	243	176	4.2	5.8	3.6	3.7	5.4	3.4	0
2	230	207	170	4.9	4.6	1.4	4.4	4.5	0.8	2.8
3	300	294	216	3.8	5.8	3	4	6.6	4.4	0
4	285	262	211	5.1	5.2	1.9	5	5.8	1.8	3.35

Table 2: Simulation and practical results of capacitor phase splitter

IV. Conclusions

The work carried out has successfully shown the operation of three phase induction motors used for the pumping operations using capacitor phase splitter on no load and load conditions in MATLAB/SIMULINK and on test bench. The parameters like voltage, current, power, speed and impact of imbalance and load are analyzed and have given clear information about the possible impacts on motors performance and life span. The study of practical implementation of capacitor phase splitter also revealed the probable imbalance that damage the three phase motor during the run of three phase motor on two phase conditions. The comparative study gives the necessity of a controller or a protective mechanism to avoid such operations to safeguard the motors. The energy policy and the regulations must be such a way set and practiced, so that the farmer should like to invest and install such on his requirement by taking technical and financial assistance.

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