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Balancing Load of Permanent Magnet Synchronous Generator based DG-Set with DSTATCOM using Hyperbolic Tangent Function based LMS-least mean square Algorithm

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Abstract:

The Permanent Magnet Synchronous Generator (PMSG) based Diesel Generator (DG)-set, has the wide area application due its high efficiency, low operational cost & maintenance cost, high power factor and self-excitation. The Permanent Magnet Synchronous Generator (PMSG) generates the constant frequency if driven at constant speed, the only challenge is to maintain constant terminal voltage which falls during heavy load condition and rises with light load condition. The proposed system consists of Permanent Magnet Synchronous Generator (PMSG) based Diesel Generator (DG)-set with Distribution Static Compensator (DSTATCOM) and Battery Energy Storage System (BESS) for load leveling, voltage management, harmonic elimination and reactive power compensation. The project deals with evaluation and performance measure of hyperbolic tangent function based Least Mean Square (LMS) algorithmic program for extracting of reference source current to control Distribution Static Compensator (DSTATCOM). The performance of Distribution Static Compensator (DSTATCOM) will be validated in MATLAB Simulink.

Keywords — **PMSG, DG-Set, DSTATCOM, BESS, LMS.**

I. INTRODUCTION

Within the recent years there are ample technologies developed supported renewable energy sources because the inadequacy of natural resources. The machine developed these days has to be high economical, low maintenance and rugged in construction. The PMSGs have accumulated application in WECS (wind energy conversion systems) attributable to their high potency and low price operational and maintenance. Most of the WECS area unit variable speed generators however on the opposite hand the DG-set are the fixed speed generators.

DG-set area unit the foremost primary supply of power provide in numerous applications like trains, remote areas, commercial, academic and industrial buildings, communication towers etc. The usually used generator in DG-set is wound-field synchronous generators that have separate exciter for voltage management and speed governor for frequency management.

The PMSG will generate constant frequency once driven at constant speed by DE (diesel engine), however the terminal voltage is variable. The PMSG are often a far better choice in these DG-set with power converters that has each voltage and frequency management. The PMSG driven by DE (diesel engine) will maintain constant load voltage and frequency with mounted capacitor-thyristor-controlled reactor underneath variable load conditions. The PMSG based mostly DG-set, the terminal voltage falls with accumulated load condition and rises with belittled load condition.

During this system a DSTATCOM with BESS is employed as a controller for voltage regulation, load levelling and fuel potency improvement for unsteady variety of loads. The hyperbolic tangent perform based mostly LMS algorithmic program is employed to manage the DSTATCOM. This method provides reduced computation, quick convergence rate and eliminates the impact of noise as compared to different LMS algorithms supported adaptation filtering.

A three-leg VSC (voltage supply converter) with bank of batteries is employed as DSTATCOM. The system is supply the assorted forms of loads like linear, nonlinear and motor loads. An RC filter area unit connected to PCC (point of common coupling) to filter the high frequency ripples from voltage. The inductors area unit connected between PCC and VSC to filter the current ripples.

The location of supply currents is finished by hyperbolic tangent perform based mostly LMS-least mean sq. algorithmic program. The supply current is calculable by management algorithmic program such PMSG is loaded with 81% to 100% for up the fuel potency.

II. PROBLEM STATEMENT

The Permanent Magnet Synchronous Generator (PMSG) based Diesel Generator (DG)-set, the terminal voltage which falls during heavy load condition and rises with light load condition. This leads to various power quality disturbances such as voltage imbalances, harmonic disturbances and reactive power disturbances. The power quality can be improved by Permanent Magnet Synchronous Generator (PMSG) based Diesel Generator (DG)-set based DSTATCOM with BESS using hyperbolic tangent function primarily based LMS (least mean sq.) algorithm.

III. OBJECTIVE

The main essence of this system is to style the technology of Permanent Magnet Synchronous Generator (PMSG) based Diesel Generator (DG)-set based DSTATCOM for voltage regulation, load leveling, harmonic elimination and fuel potency improvement when feeding unsteady kind of loads. The analysis of DSTATCOM is done by MATLAB Simulink and the hyperbolic tangent function based LMS algorithmic rule is employed for management of DSTATCOM.

IV. SYSTEM CONFIGURATION

The system construction consist of PMSG with prototype DE as a prime mover as shown in figure 1. Three legs VSC with BESS are used as DSTSTCOM.

In this system used various types of loads such as linear, non-linear, balanced, unbalanced and motor load. An RC filter is connected at the point of common coupling of filters with high frequency ripples, harmonic from the voltage at PCC.

In this configuration interface the inductor between PCC and VSC for filtering the current ripples.

The reference source currents are forecast using a variable learning rate based on the hyperbolic tangent function based LMS algorithm. The reference sources are forecast using the proposed current control algorithm. Such that the PMSG is always loaded between 80% to 100% and the rated capacity of PMSG for increased full efficiency.

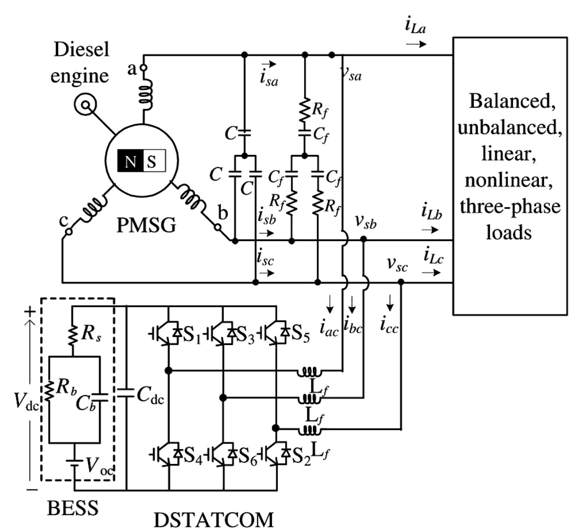

Fig. 1 System configuration of PMSG-based DG set

V. SYSTEM DESIGN

The proposed system used a particularly designed 3 phase PMSG of 3.7 kw with supply frequency of 50 Hz. At 4 poles 230V, connected in star connection at a 1500 rpm are given in appendix.

Design of interfacing inductor and RC filter is given follows.

A. Design of AC Inductor

To interface the inductor L_f between PCC and VSC is given as,

$$L_f = \frac{\sqrt{3} m V_{dc}}{12 a f_s I_{cr(p-p)}}$$

where f_s is the switching frequency, $I_{cr,p-p}$ represents ripple peak to peak current ripple of DSTATCOM, V_{dc} represents dc bus voltage, a represents an overload factor, and m represents the modulation index. In worst case,
DSTATCOM may have to take 80% of rated current of the generator which is 7.5 A. Assuming 20% of ripple content, the ripple current ($I_{cr,p-p}$) is 1.5 A. Taking f_s = 10kHz, V_{dc} = 415V, m = 1, and a = 1.2, the calculated value of L_f is 3.3 mH, and it is selected to be 3.5 mH in this investigation.

B. Ripple Factor

A first order high pass RC filter is connected at PCC to filter the high frequency voltage ripples. The values of R&C are selected such that the impedance offered by the filter is low to high frequency and it is a high for line frequency.

C. Excitations Capacitors

A machine used in the proposed system is a 230V permanent magnet synchronous machine (PMSM) giving an a open circuit voltage of 180V when operated as a generator. So, an excitation capacitor bank of 2.5kVAR is connected at its terminals to give a no-load terminal voltage upto 220V.

D. DC Link Capacitors

The design of dc link capacitor (C_{dc}) of VSC is operated by the ability of VSC to overcome transient. It totally depends upon maximum and minimum battery voltage and energy supplies to come across demand during transient.

$$\frac{1}{2}C_{dc}\,[V_{dc}^{2} - V_{dc1}^{2}] = (\Delta P)T$$

E. Selection of Battery Voltage

For satisfactory operation, the voltage at dc link of DSTSTCOM must be kept more than double the peak value of the phase voltage of the system.

$$V_{dc} = \frac{2\sqrt{2}\,Vll}{\sqrt{3}m}$$

VI. HARDWARE IMPLEMENTATION

The real time implementation of this PMSG based DG system is carried out with a specially designed 3.7KW at line frequency 50Hz, 4 pole. 230V. the PMSG driven at constant speed with an induction motor of 5.5 KW to fed from a variable frequency drive. the induction motor is used to simulate a DE.

A digital signal processor (DSP) consist of a DSP (dSPACE DS1104), Hall's effect voltage sensors (LEM LV 25-P), Hall's effect current sensors(LEM LA 55P),gate isolation circuits,three leg VSC and a 412v,7Ah battery bank. The voltage at PCC is sensed with two Hall's effect voltage sensors.Two source currents (isa,isb) and three load currents (iLa,iLb,iLc) are sensed with five Hall's effect current sensors.The ADC channels DSP to covert the sensed voltage and current signals to digital signals. This signal are used in hyperbolic tangent based on LMS algorithm to forecast reference source currents. This reference source currents are compared with sensed source currents to generate gating signals. This gating signals taken out through the digital input of DSP and fed to the input of optocoupler (6N136) and to gate driver circuit of VSC. The battery bank is connected on DC link of the VSC of DSTATCOM as BESS.

VII. RESULTS

Test result of PMSG-based prototype of DG set has been recorded directly on a developed prototype under various loading conditions with and without DSTATCOM. Performance of the system under different types of loads such as linear, nonlinear, and motor loads under steady-state and dynamic conditions is discussed as follows

F. Performance without DSTATCOM

In this case, the terminal voltage of PMSG falls during heavy load condition and rises with light load condition. This leads to various power quality disturbances such as voltage imbalances, current imbalances and harmonic disturbances.

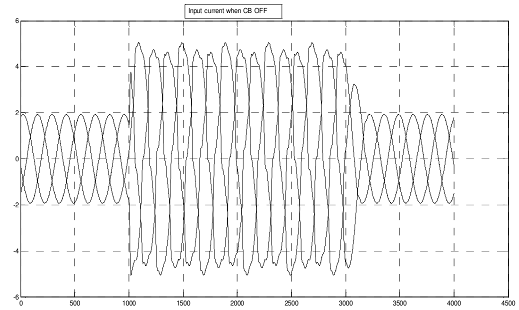

Fig. 1 Input Current (w/o DSTATCOM)

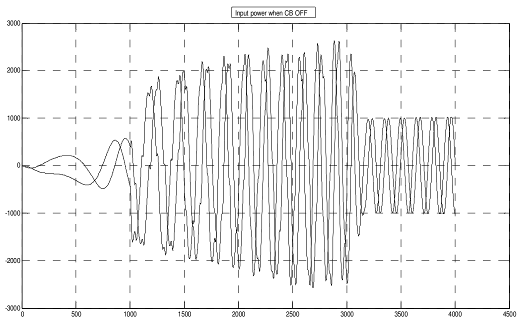

Fig. 3 Input Power (w/o DSTATCOM)

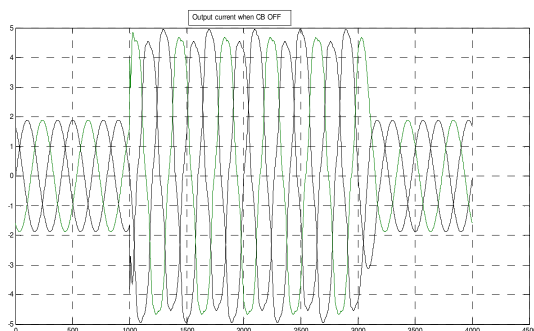

Fig. 4 Output Current (w/o DSTATCOM)

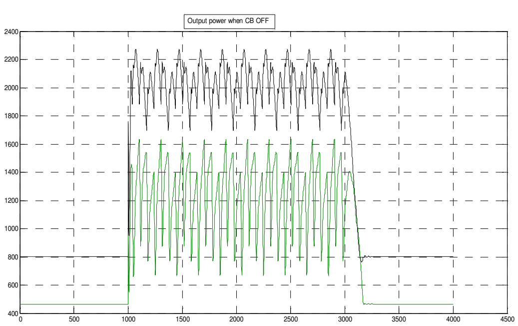

Fig. 5 Output Power (w/o DSTATCOM)

G. Performance with DSTATCOM

During light load conditions, the power is fed to the battery, and during heavy load conditions, the power is taken from the battery to meet the excessive load. So, the system is able to provide load leveling. The controller maintains terminal voltage at a constant level under all the loading conditions.

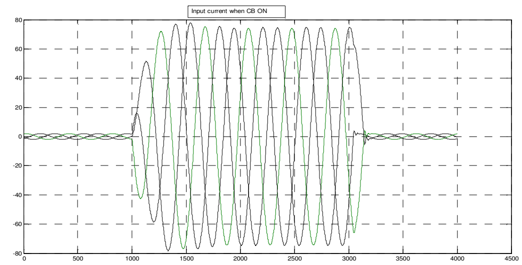

Fig. 6 Input Current (with DSTATCOM)

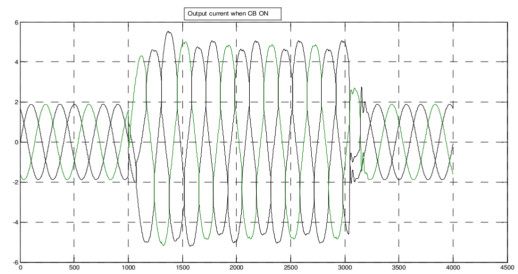

Fig. 7 Output Current (with DSTATCOM)

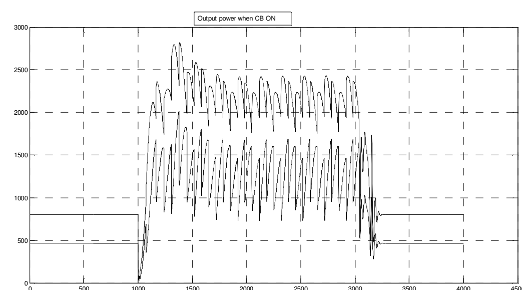

Fig. 8 Input Power (with DSTATCOM)

H. THD Performance with & without DSTATCOM

The controller has eliminated the harmonics of the source voltage and current and kept the harmonics distortion within 5% even under nonlinear loads. The controller has been found fast enough to overcome the transient with one cycle during load variation or unbalancing. Therefore, overall performance of the system is quite satisfactory under all the types of loading conditions.

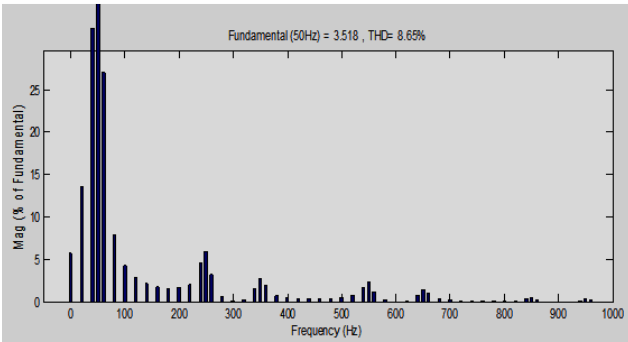

Fig. 9 THD w/o DSTATCOM

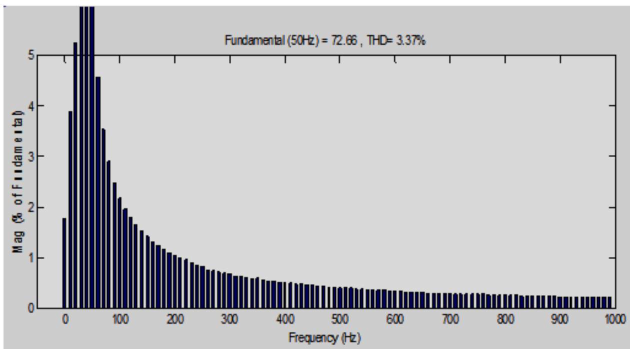

Fig. 10 THD with DSTATCOM

VIII. CONCLUSION

This paper shows an outline of the planned DSTATCOM using hyperbolic tangent function based function based least mean sq. (LMS) Algorithm. The performance of the planned system for load levelling and voltage control for PMSG-based DG set will be tested underneath numerous loading conditions. The performance of the system can be shown quite satisfactory underneath all the kinds of loading conditions for better voltage control and harmonic elimination.

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