Management of Power in AC/DC Hybrid Microgrid and its Harmonic Analysis by using D-STATCOM

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Abstract: ***In the present scenario, the increasing penetration of solar energy can be significant challenge due to the variation of power generation. One of the solution to improve the quality of power supply and guarantee of system stability is energy storage system(ESS). In this project, a AC-DC hybrid micro grid is designed based on photovoltaic (PV), generator and energy storage system are coordinated control is proposed to manage the power according to the load demand With D-STATCOM and without D- STATCOM. Moreover, AC-DC buses are interconnected by the bidirectional converters. The power control of the interlinked converters is enabled when the AC or DC side suffer from the active power demand shortage. In particular, if the AC micro grid doesn't satisfy the reactive power demand, then the distributed static synchronous compensator (D-STATCOM) is used for the compensation. A DC-DC Boost converter is connected to boost out the input voltage from the photovoltaic (PV)farm which is given to DC-bus. The system is tested with a different load i.e. inductive, pulse, non-linear load connected to the AC-side. The proposed topology is verified by doing simulation of MATLAB R2016b for management of power between two AC and DC sides under normal conditions and fault conditions with high efficiency, reliability and robustness in islanding mode.***

Keywords: Hybrid micro grid, PV system, ESS, D-STATCOM, THD

1. Introduction

The introduction of renewable power generation such as photovoltaic (PV) and wind generation is emerged out rapidly. The concept of the Hybrid micro grid [1] includes in distributed control scheme, voltage, power and energy management with solar energy, energy storage and critical load. A bidirectional AC-DC inverter is used to interconnect the AC & DC sides by controlling in active and reactive power flow between them. A new coordinated voltage control (CVC) method with reactive power management scheme (RPMS) [2], achieves the enhancement of voltage profile and transient response. Because of increasing of load demand along with the necessity of cost reduction and higher reliability requirements. It's necessary to know about the power quality improvement of the hybrid power system which is compensated by STATCOM. A hybrid AC/DC model has been propose [3] not only to reduce the multiple conversion loss but also to compensate Active(P) and reactive power (Q) problems. One of the major issue in any hybrid micro grid [4]. The degradation of power quality which can be compensated by using shunt active power filter. The penetration of renewable energy sources for power generation becomes very popular as because of the challenges facing because of environmental pollution. One of the areas of increasing in the introduction of photovoltaic (PV) cells within power electronics. A new kind of invention [5] that can replace the existing inverter of a small to medium sized permanent magnetic wind machine (10KW to 20 KW) that can offer VAR control and power factor correction in a dynamic manner. That inverter is called D-STATCOM inverter which can provide grid with VAR control and power factor correction.

The proposed reactive power compensation technique is based on the voltage sag and the power flowing in the line. The three phase D-STATCOM [6] compensates the reactive power deficiency in the phase when distributed generators (DG) supply "Maximum available active power". Because of the application of non-linear loads such as transformers, computers, saturated coils and sophisticated power electronics devices are introduced in to the distribution systems [7]. Because of their non-linear characteristics and fasting switching action, power electronics devices create unwanted harmonics in the system. It causes many problems like low system efficiency and poor power factor. It also affect to other consumers. Hence it is very important to overcome these undesirable features. The shunt active filter, D-STATCOM use to suppress the harmonics [8]. With the proposed method; the reactive power from micro grids are controlled to mitigate the voltage change cause by the active power from the hybrid micro grid and simultaneously, the D-STATCOM is activated to suppress the harmonics originated from renewable power generators and integration of STATCOM [9]. With energy storage device plays an important role in improving the performance of the system. However, the D-STATCOM is active power filter (APF) [10] reduce the high voltage stress across each power switch. In order to satisfy the demanded power with maximum utilization of renewable resources [11], the tolerance of the supervising controller are applied in the AC/DC micro grid. Moreover, the tolerance of the proposed power management system towards energy storage system is failure in hybrid micro grid is also incorporated in the overall control scheme. The coexistence of both AC and DC micro grids [12] can fulfill the power demand of customer at any cost. Thus the project presents an overview of power management strategies for a hybrid AC/DC micro grid system [13], which includes different loading conditions.

2. Modeling of Hybrid Microgrid

The concept of microgrid is considered as a collection of loads and microsources which functions as a single controllable system that provides both power and heat to its local area. This idea offers a new paradigm for the definition of the distributed generation operation. To the utility the microgrid can be thought of as a controlled cell of the power

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system. For example this cell could be measured as a single dispatch able load, which can reply in seconds to meet the requirements of the transmission system. To the customer the microgrid can be planned to meet their special requirements; such as, enhancement of local reliability, reduction of feeder losses, local voltages support, increased efficiency through use waste heat, voltage sag correction [14]. The main purpose of this concept is to accelerate the recognition of the advantage offered by small scale distributed generators like ability to supply waste heat during the time of need [15]. The microgrid or distribution network subsystem will create less trouble to the utility network than the conventional microgeneration if there is proper and intelligent coordination of micro generation and loads [16]. Microgrid considered as a 'grid friendly entity" and does not give undesirable influences to the connecting distribution network i.e. operation policy of distribution grid does not have to be modified.

2.1 Configuration of the Hybrid microgrid

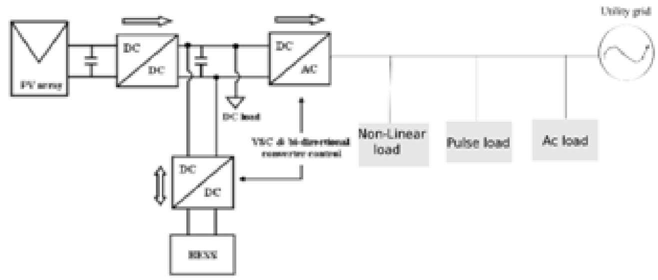

Figure 1: A Hybrid AC/DC Microgrid system

The configuration of the hybrid system is shown in Figure 1 where various AC and DC sources and loads are connected to the corresponding AC and DC networks. The AC bus of the hybrid grid is tied to the utility grid.

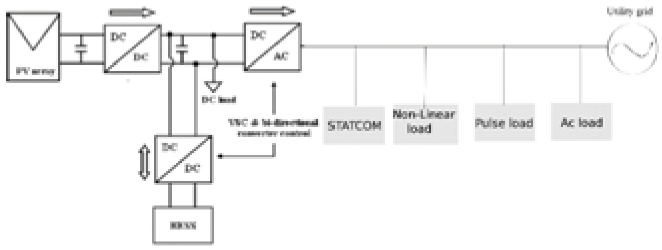

Figure 2: A Hybrid AC/DC Microgrid system with D-STATCOM Controller

The configuration of the hybrid system is shown in Figure 2 where a STATCOM is connected on the AC-side of the hybrid system.

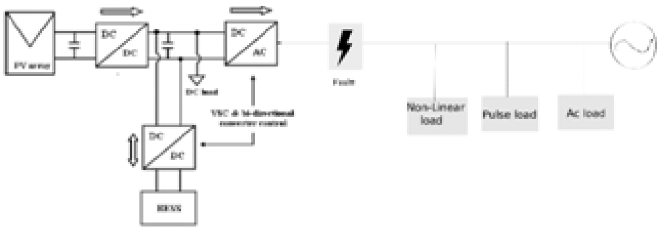

Figure 3: A Hybrid AC/DC Microgrid system with Three-phase fault

The configuration of hybrid system is shown in Figure. 3 is the system is effected with the Three-phase fault.

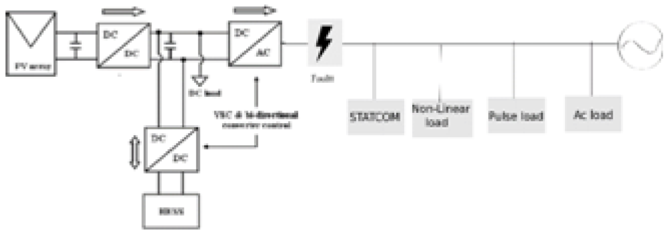

Figure 4: A Hybrid AC/DC Microgrid system with Three-phase fault and D-STATCOM

The configuration of hybrid microgrid system is effected with three-phase fault and a FACT device is installed i.e STATCOM.

Table 1: Hybrid AC/DC MIcrogrid system parameters

Symbol	Description	Value
CPV	Solar panel capacitor	100µF
LPV	Inductor for solar panel boost converter	5mH
Cd	DC bus capacitor	6000µF
Lac	AC filter inductor	1.2mH
Rac	Inverter equivalent resistance	0.3Ω
Lb	Battery converter inductor	3.3mH
Rb	Resistance of Lb	0.5Ω
f	Rated AC grid frequency	50Hz
Vd	Rated DC bus voltage	300V
Vm	Rated AC bus p-p voltage (rms)	208V
n1/n2	Transformer ratio	1:1

3. Simulink model of AC/DC Hybrid Microgrid

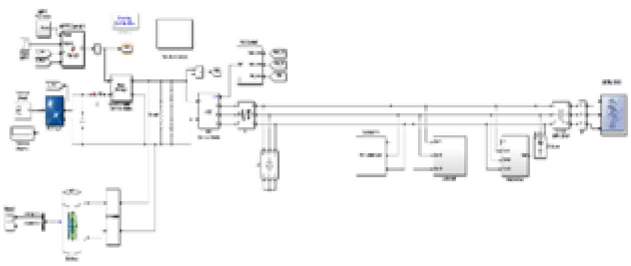

Figure 5: Hybrid microgrid with different load conditions at normal operating mode.

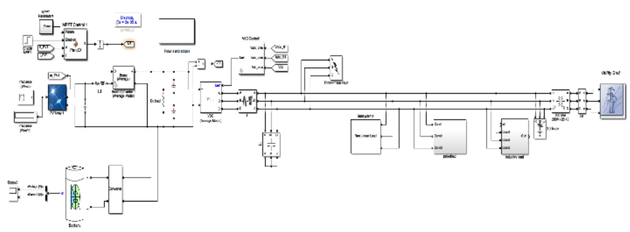

Figure 6: Hybrid microgrid with different load conditions at fault operating mode.

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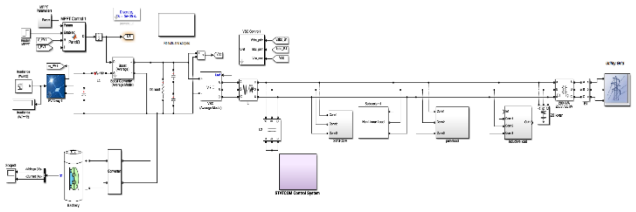


Figure 7: Hybrid microgrid with different load conditions at normal operating mode with STATCOM.

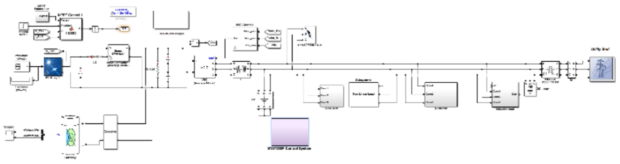


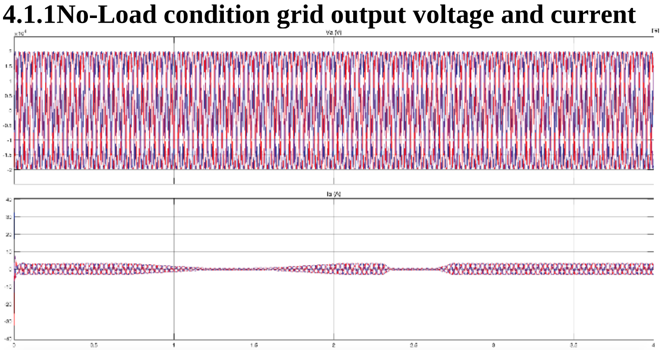
Figure 8: Hybrid microgrid with different load conditions at fault operating mode with STATCOM.

4.Effect of discrepncy of loading conditions on hybrid microgrid

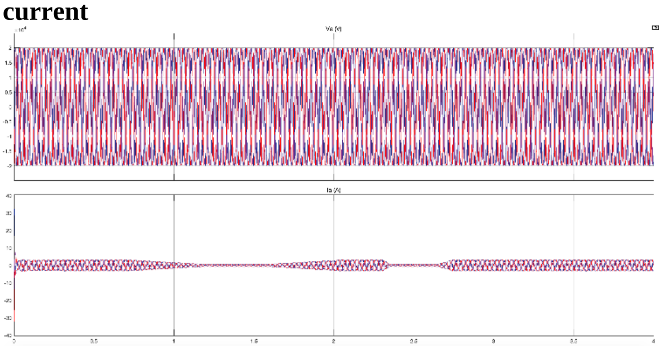
4.1 Variation of loading conditions without D-STATCOM

By adding the different types of the loads on hybrid microgrid , the power quality of the system is determined.

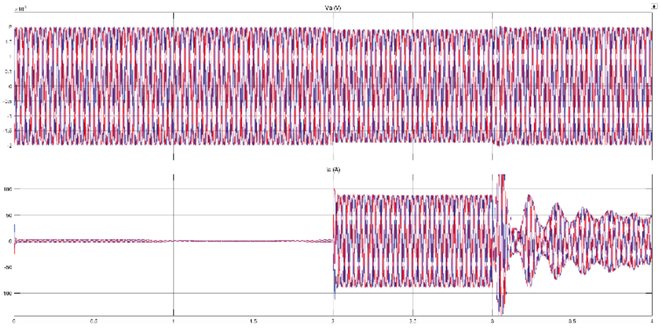
4.1.1No-Load condition grid output voltage and current



4.1.2 Inductive load condition grid output voltage and current



4.1.3 Inductive & Pulse load condition grid output voltage and current



4.1.4 Inductive, Pulse, Non-linear load condition grid output voltage and current

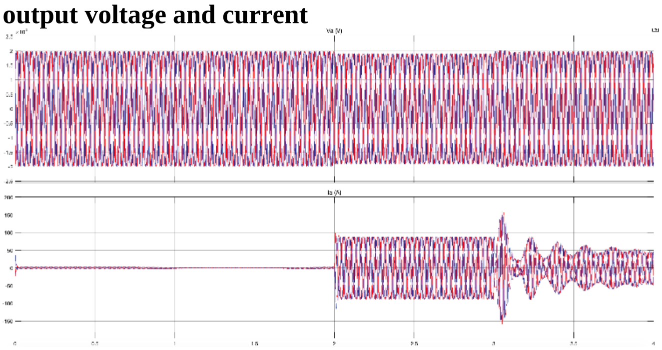


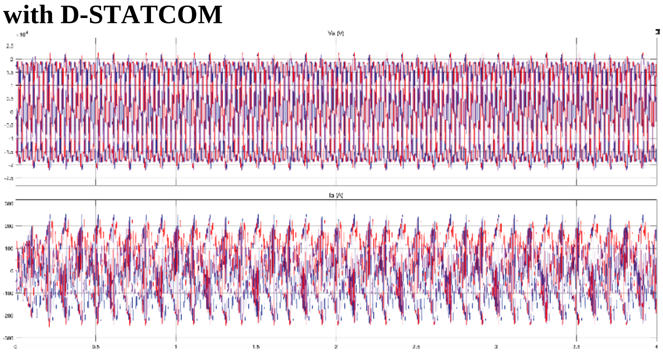
Table 2:

loads	Active power	Reactive power	%THD (V)	%THD (A)
Noload	9.0e+04	-41.9	0.83	100.15
inductive	9.0e+04	-58.6	0.84	141.10
Inductive &pulse	-1.2e+06	4.95e+05	1.94	82.94
Inductive, pulse& nonlinear	-1.2e+06	4.90e+05	0.99	148.09

4.2 Variation of loading conditions with D-STATCOM

By adding different types of loads on the hybrid microgrid with STATCOM the power quality of the system is determined.

4.2.1 No-Load condition grid output voltage and current with D-STATCOM



4.2.2 Inductive load condition grid output voltage and current with D-STATCOM

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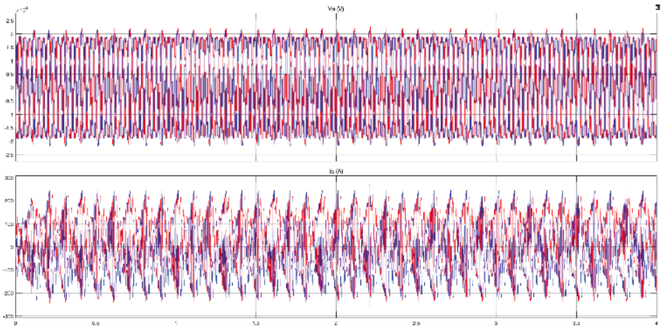
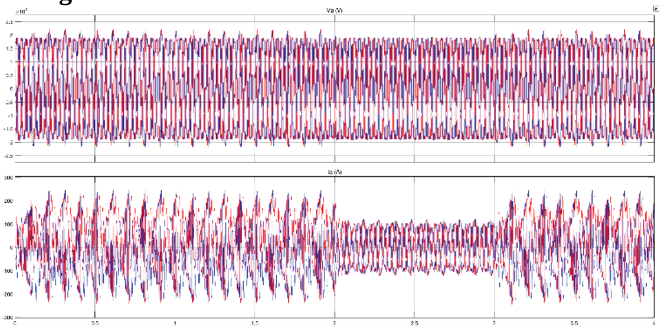


4.2.3 Inductive & Pulse load condition grid output voltage and current with D-STATCOM



4.2.4 Inductive, Pulse, Non-linear load condition grid output voltage and current with D-STATCOM

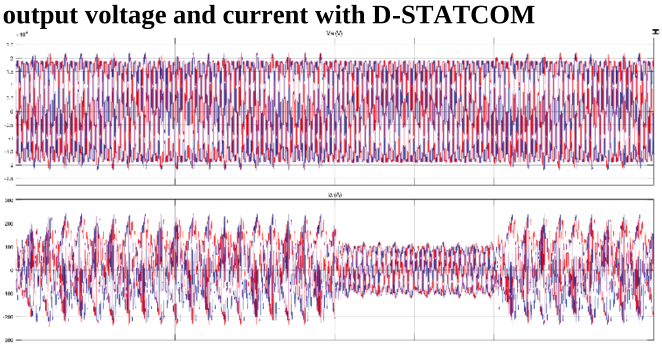


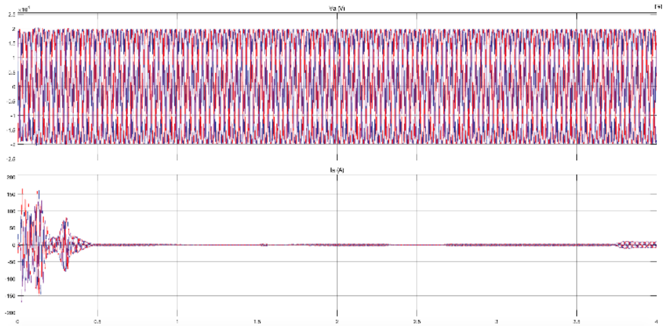
Table 3:

loads	Active power	Reactive power	%THD (V)	%THD (A)
Noload	4.5e+06	-1.6e+06	0.62	9.06
inductive	-5.6e+06	-1.7e+06	0.60	8.09
Inductive &pulse	-4.5e+06	-1.4e+06	0.48	9.22
Inductive, pulse& nonlinear	-4.6e+06	-1.4e+06	0.48	9.13

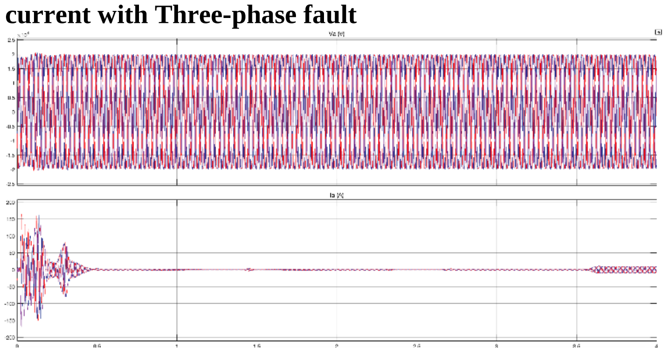
4.3 Variation of loading conditions with Three-phase fault

By adding the different types of the loads on hybrid microgrid, and making three-phase fault the power quality of the system is determined

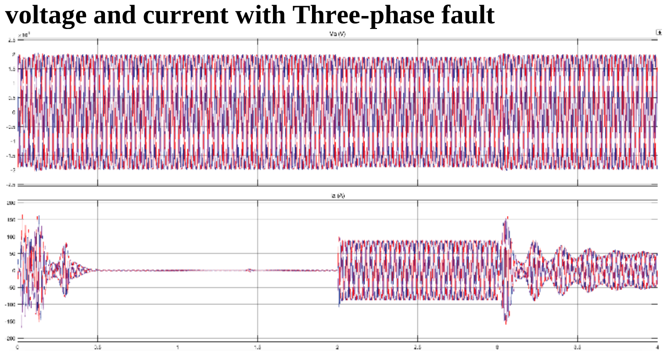
4.3.1 No-Load condition grid output voltage and current with Three-phase fault



4.3.2 Inductive load condition grid output voltage and current with Three-phase fault



4.3.3 Inductive & Pulse load condition grid output voltage and current with Three-phase fault



4.3.4 Inductive, Pulse, Non-linear load condition grid output voltage and current with Three-phase fault

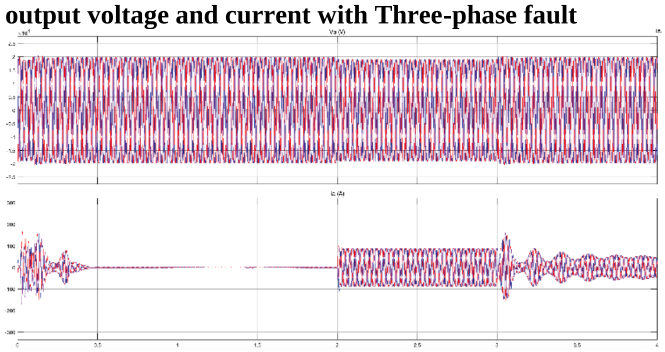


Table 3:

loads	Active power	Reactive power	%THD (V)	%THD (A)
Noload	-1.2e+06	4.3e+05	3.48	110.18
inductive	-1.1e+06	4.2e+05	0.89	141.10
Inductive &pulse	-1.2e+06	4.5e+05	2.23	158.76
Inductive, pulse& nonlinear	-1.2e+06	4.4e+05	0.92	167.65

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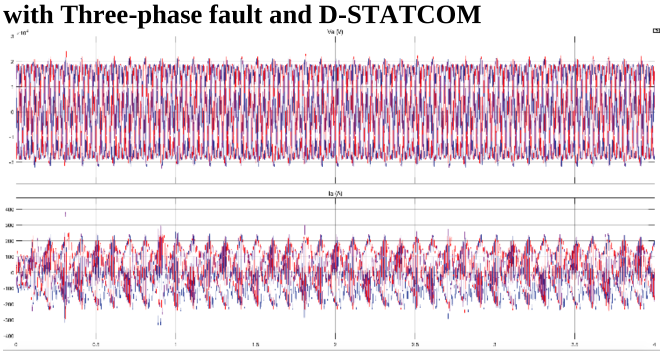
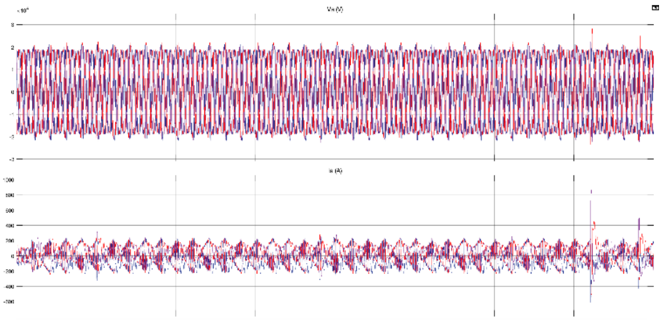
4.4 Variation of loading conditions with three-phase fault and D-STATCOM

By adding the different types of the loads on hybrid microgrid , and making three-phase fault the power quality of the system is determined

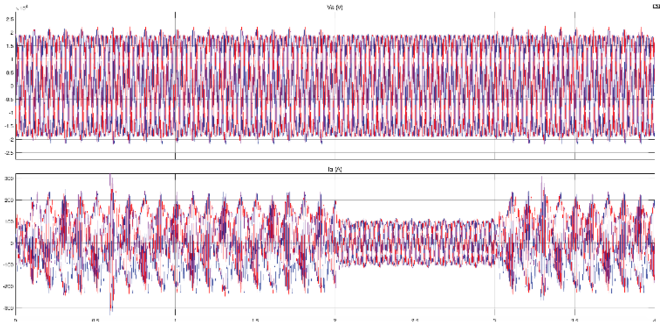
4.4.1 No-Load condition grid output voltage and current with Three-phase fault and D-STATCOM



4.4.2 Inductive load condition grid output voltage and current with Three-phase fault and D-STATCOM



4.4.3 Inductive & Pulse load condition grid output voltage and current with Three-phase fault and D-STATCOM



4.4.4 Inductive, Pulse, Non-linear load condition grid output voltage and current with Three-phase fault and D-STATCOM

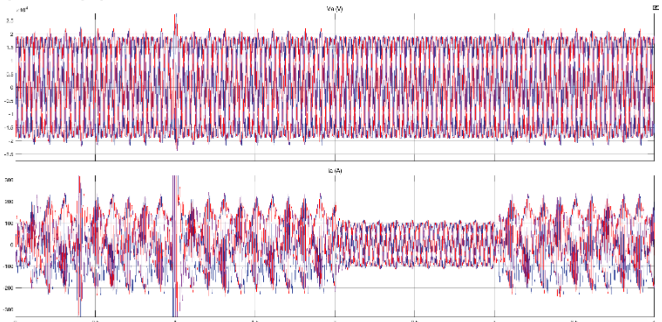


Table 4:

loads	Active power	Reactive power	%THD (V)	%THD (A)
Noload	-4.7e+06	-1.6+06	0.83	2.32
inductive	-4.5e+06	-1.5e+06	0.60	8.36
Inductive &pulse	-4.6e+06	-1.4e+06	0.48	9.22
Inductive, pulse& nonlinear	-4.5e+06	-1.4e+06	0.48	9.13

5. Results and Discussion

In this paper a coordination power flow between AC/DC and vice versa is proposed. The DC side voltage is boosting by using P&O algorithm in MPPT control. The percentage of harmonic distortion(THD) is calculated and observed that the average %THD value is drastically reduced from 118.07 to 8.875.The ac side voltage amplitude and frequency are regulated by bidirectional AC/DC inverters by considering different loading conditions. To satisfy the load demand, active and reactive power is compensated by taking a FACTS control device, STATCOM. It has been seen that when load demand increases the active power is decreasing and reactive power is increasing as shown in the Table 2. To compensate the power a STATCOM is connected on the AC side of the hybrid (AC/DC) system. The harmonic analysis has been done by taking the different loading conditions as shown in Table 3. To analyse the power quality of proposed system, a three-phase fault was is initiated without STATCOM and the percentage of total harmonic distortion(THD) calculated. And it has been observe the average %THD value is drastically reduced from 144.42% to 7.25%.

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