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A Novel Approach for Stochastic Reactive Power Management in Micro-Grid System with Renewables

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ABSTRACT: The undesirable reverse power flows and voltage fluctuations due to renewable generation, demand response, and electric vehicles may impose new challenges on the operational conditions of the Distributed Micro-Grid System (DMGS). When the Photo-Voltaic (PV) operators have the right investment incentives, the modern advances in the Photo-Voltaic (PV) inverters offer new opportunities for reactive power management. In this project we proposed a novel algorithm for the stochastic reactive power management in a distributed generation based Micro-Grid System (MGS) using an Adaptive Reactive Power Compensation and Regulation Unit (ARPC&RU) along with its associated control circuitry with renewable Distributed Power Generation Unit (DPGU)s. Generally the reactive power compensation is considered as an ancillary service. Accounting for the increasing time-variability of distributed generation and demand to counteract to the power losses due to an undesirable reactive power flow, a stochastic reactive power compensation scheme is proposed. When an uncertain active power injection occurs, the proposed reactive power control scheme which is distribution-free and relies solely on power injection data will be employed and switched into action to compensate the power loss due to an injected reactive power component. The fault protection of the proposed Distributed Generation (DG) based micro-grid network is performed with an aid of another defensive module called a Fault Regulation Circuit (FRC). Thus the proposed algorithm is designed to perform the fault isolated reactive power compensation in the DG based MGS. Numerical tests on an industrial 12-bus MGS are conducted in the Matlab environment and the simulation results corroborate the reactive power management efficiency of the novel stochastic scheme over the traditional existing techniques.

KEYWORDS: DMGS, Wind-Farms, Photo-Voltaic, DG, Fault, FRC, OPF and ARPC&RU.

I. INTRODUCTION

Medium and low-voltage power grids nowadays are undergoing a transformative change to microgrids. Micro-Grid is a very huge complex power distribution network with complex network architecture [1]. It is a centralized power distribution network which supplies its power to all the regions surrounding it. The micro-grid network accepts the power from various non-renewable and renewable power generation units. The non-renewable type power generation units supply the power with almost required quality controlled by the system with the proportional consumption of the non-renewable energy resources. Generally the strength and quantity of the renewable energy resource will vary continuously from time to time and season to season. Thus the strength and quantity of the renewable energy resource cannot be maintained as constant. Hence the generated power levels from the renewable energy resources will vary accordingly. When the Distributed Generation (DG) [2] based renewable power generation units are also used as the power source for the micro-grid system, the fluctuating power levels from the DG unit may cause the injection of the reactive power levels. Whereas the non-renewable energy resource based power generation units [4] will inject the active power components. The undesirable injection of the reactive power levels against the active power levels may cause spurious fluctuations in the quality of power being supplied by the micro-grid network.

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Distribution Generation (DG) plays important role in delivering the power into the distribution system. However, power losses and voltage magnitude must take into consideration in order to produce reliable power to consumer. Renewable generation and elastic loads are uncertain, power flows are frequently reversed, and bus voltage magnitudes can fluctuate considerably. For example, the power generated by a photo-voltaic (PV) network[3] with intermittent cloud coverage can vary by 15% of its name plate capacity within one-minute intervals. Different from transmission grids, bus voltage magnitudes in distribution grids are markedly affected by active power variations. On a clear day, solar generation may easily exceed local demand (especially at midday off-peak hours) and cause over-voltages ; whereas overnight vehicle charging could lead to serious voltage sags . Although prohibited by current standards, the power electronics of PVs can be commanded to provide reactive injections as well. For this reason, reactive power compensation via DG units has been an active research area lately. All previous schemes build on approximate grid models. Being an instance of the optimal power flow (OPF) problem[5], reactive power management is a non-convex problem, yet several convex relaxations have been proposed . In radial distribution grids, OPF can be surrogated by a semi definite program (SDP)[7] or by a second-order cone program (SOCP) using either polar coordinates, or the branch flow model. Generally a micro-grid is a giant class power distribution network which will supply its power to all the regions surrounding it. Unfeasible reactive power injections can cause remarkable drop in the quality of the power being supplied by the micro-grid network[6]. This power quality fluctuations not only affects the power quality in power systems and cause losses for both electric utilities and customers. Several algorithms were proposed to compensate for the reactive power injections and the performance of which was not satisfactory. In addition to the reactive power injections, sometimes the frequent line faults due to several natural disasters and atmospheric conditions may cause the sudden drop in the power quality and can destruct the power distribution network, disturbs the quality of power supplied to the utilities. In order to counteract to these issues we proposed this approach for the protected and rated quality operation of the micro-grid system.

II. LITERATURE REVIEW

In a Distributed Micro-Grid System (DMGS), the occurrence of line faults is very frequent due to natural threats to the lines and their ageing. In a big Micro-Grid network a fault is occurred at one corner part of the network shows a serious impact on the entire network by causing a severe deviation in its operation there by leading to shut-down of the entire network until or unless the fault was detected and isolated. In order to resolve the above issues D Haris Khan and K Veera Sekhar proposed a novel algorithm in[20] for DMGS security by replacing IEDs in former algorithm with Phasor Measurement Units(PMUs)which determines the occurrence of the faults based on the analysis of voltage and current phasors of Power Distribution Bus (PDB) lines. The method exploits the nodal voltage and mesh current analysis where the phase voltage, impedance and admittance matrices of the network and its dual circuit are developed and utilized for smooth detection and isolation of faults without network malfunction. In addition, this method not only detects and isolates the faults but also informs the same to the technical department for immediate correction. The PMUs are organized as independent region monitoring devices controlled by the control unit of DMGS. This methods detects, locates and isolates the line faults, but it cannot protect the grid from the reactive power flows.

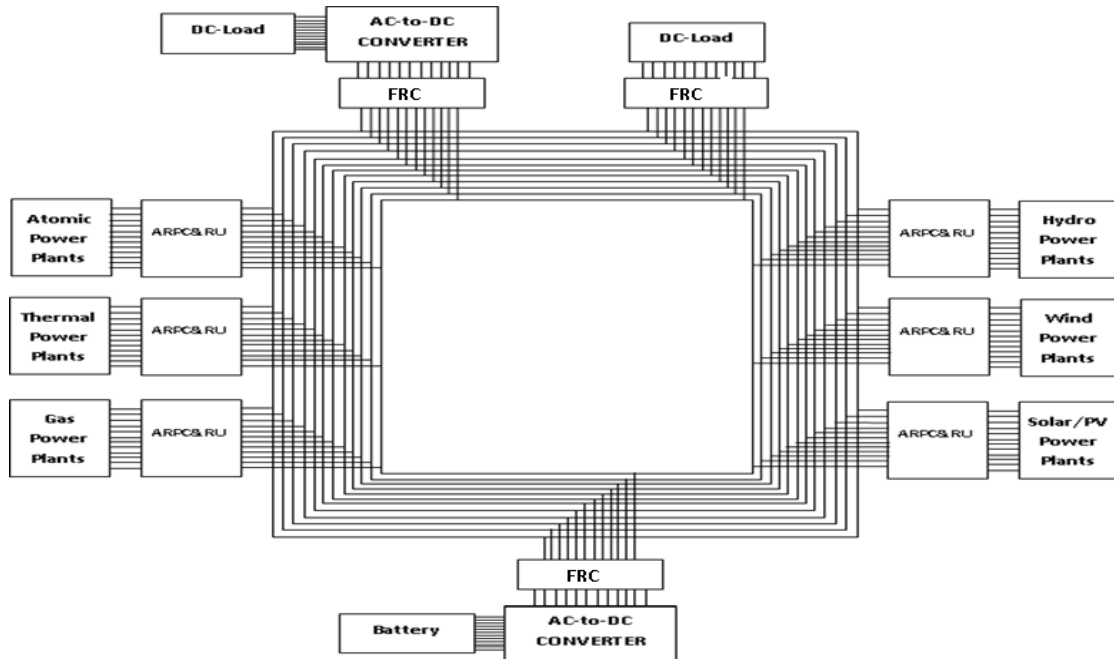
III. PROPOSED WORK

In this project we proposed, designed and developed a novel method for the stochastic reactive power management in a DG based Micro-Grid System (MGS)[8][9] using an ARPC&RU unit along with its associated control circuitry and DPGUs. Being a huge power distribution network an MGS accepts power in massive quantities from both renewable and non-renewable power generation units. Non-renewable power generation unit[10] can serve the rated quality power with the proportionate consumption of non-renewable energy resources. Whereas the power from

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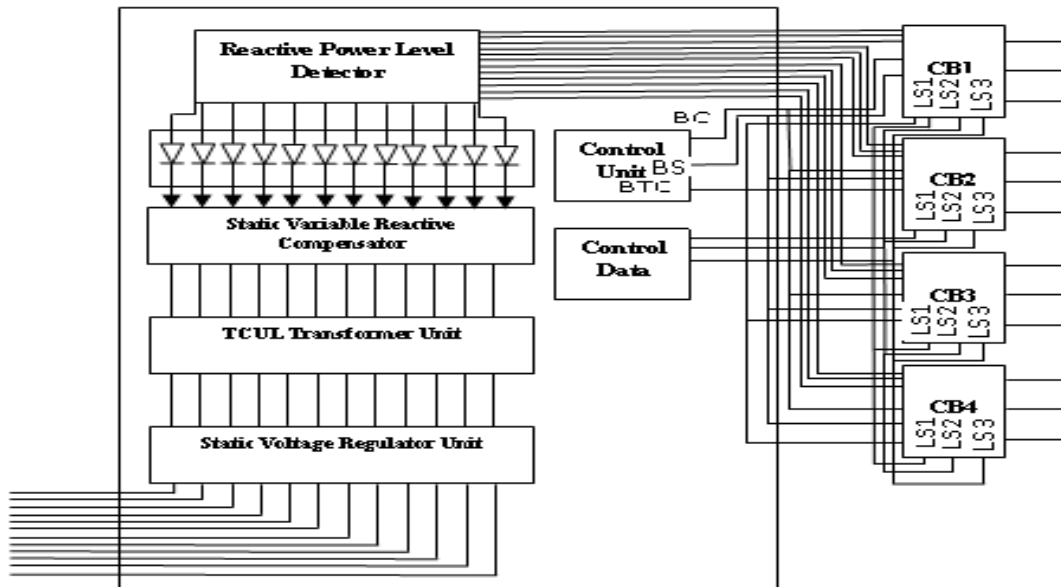
Fig(1):Schematic Block Overview of the proposed DMGS.

renewable power generation unit. Whereas the strength and quantity of the renewable energy resources vary continuously from time-to-time, season-to-season and hence the quality and quantity of the power generated by the renewable power generation units will vary proportionally[11]. Due to these continuous power fluctuations, the renewable power generation units will inject the reactive power levels into the Micro-grid system. The non-renewable power generation units will inject the active power levels into the micro-grid network[12]. The reactive power levels injected into the network may significantly cancel the active power levels in the micro-grid network there by leading to the reduction of the overall quality of the power supplied by the micro-grid system[13]. As an Eternal solution to this ever teasing problem we proposed this project. The proposed DMGS is implemented with an IEEE-12 line ring bus like architecture as shown in fig(1).The ring bus architecture enables the DMGS to receive the power from all surrounding power generation units and to serve it to all the surrounding regions.All the surrounding power generation units are connected to the DMGS through the proposed ARPC&RU units. This ARPC&RU unit cancels the reactive power flows from DMGS to the generation units and delivers the rated power to the grid[14][15]. An identical bus branch is drawn from the DMGS to each region surrounding it. All the individual bus branches drawn to various surrounding regions from the DMGS are put under the control of an identical Fault[1] Regulation Circuit(FRC) module.DMGS will have a complete command and control over all FRC and ARPC&RU modules as shown in fig(1) with the help of three control signals drawn from all ARPC&RU and FRC.ARPC&RU_CN, ARPC&RU_S and ARPC&RU_ES are the control signals corresponding to the ARPC&RU unit representing the control, status and error status of the respective ARPC&RU unit.In a similar manner FRC_CN,FRC_S and FRC_ES are the

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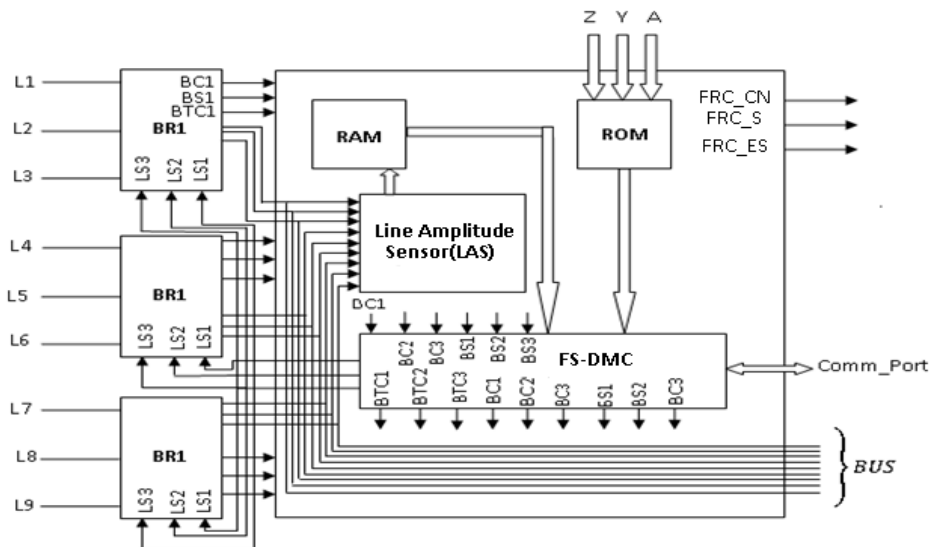
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Fig(2):Internal architecture of the ARPC&RU unit.

control signals corresponding to the FRC unit evincing the control, status and error status of the respective FRC unit. Schematic architecture of the proposed ARPC&RU unit is shown in fig(2),which internally consists of a Reactive Power Level Detector(RPLD) which senses the reactive power flow levels and informs the same to the Static Variable Reactive



Fig(3):Internal architecture of FRC .

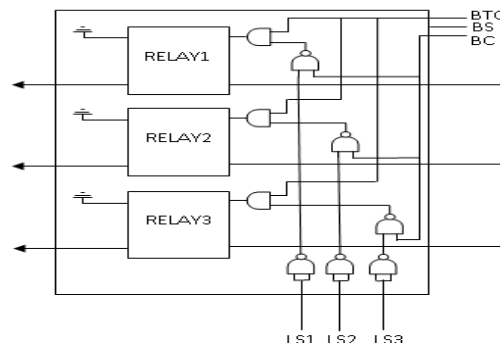
Compensator(SVRC) .SVRC cancels the reactive power flows and allows only rated quality power to flow from generation unit to the grid. The Tap-Change-Under-Load Transformer unit(TCUL-TU) restores the degraded power levels to their rated counter parts and the Static Voltage Regulator Unit(SVRU) regulates the floating flow to the constant regulated level. The control unit controls all the internal blocks and associated breakers. The fault

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protection[1] activities of the DMGS are controlled and monitored by the FRC unit whose internal architecture is shown in fig(3).FRC module consists of a RAM unit,a ROM unit,a Line Amplitude Sensor(LAS),a Fault Sensing and Decision Making Circuit(FS-DMC) and the associated breakers as shown in fig(3).The objective of ROM unit is to store the standard bus parameter values from the database of the DMGS.The RAM unit acts as a volatile temporary storage media for the instantaneous bus parameter values computed by the LAS unit. The instantaneous and standard bus parameter values are compared for fault detection in FS-DMC unit. Based on the comparison results the FS-DMC unit will acts accordingly to locate and isolate the faults without causing any interrupt for power distribution. The power levels on various power distribution bus lines are monitored and controlled by the FRC unit with the help of its associated breakers.FRC unit controls all its associated breakers with the help of three control signal lines such as BC(Breaker Control),BS(Breaker Status) and BTC(Breaker Trip Control).The internal architecture of the breaker circuit is shown in fig(4),which consists of three relays and an associated logic circuitry to control three power distribution lines. All breakers are identical in their structure and each can control three lines simultaneously with its associated logic circuitry.



Fig(4):Internal architecture of breaker circuit.

IV. RESULTS AND DISCUSSION

To verify the operational effectiveness of the proposed DMGS [16], the computer simulations have been performed using MATLAB.The simulation results of the proposed method are presented hierarchically as follows.

Micro-Grid Rated Parameter Values			
S NO	Grid_Current	Grid_Voltage	Grid_Phase
1	50	230	0
2	50	230	30
3	50	230	60
4	50	230	90
5	50	230	120
6	50	230	150
7	50	230	180
8	50	230	210
9	50	230	240
10	50	230	270
11	50	230	300
12	50	230	330

Table(1):MGS rated parameter values.

Wind-Farm Performance Statistics					
S NO	WF1_A	WF1_V	PDS_S1	RFC_PL1	TCULTU_RPL1
1	50	230	1	230	230
2	50	230	1	230	230
3	50	230	1	230	230
4	50	230	1	230	230
5	50	230	1	230	230
6	50	230	1	230	230
7	50	230	1	230	230
8	50	230	1	230	230
9	50	230	1	230	230
10	50	230	1	230	230
11	50	230	1	230	230
12	50	230	1	230	230

Table(2):Wind-Farm performance statistics.

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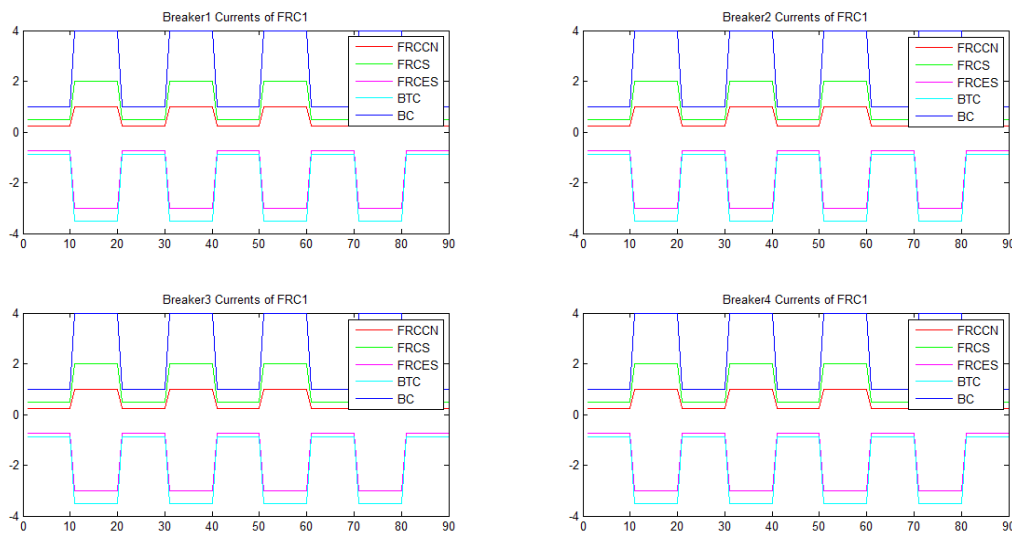
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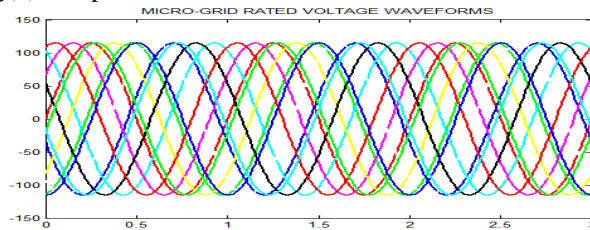
FRC OPERATIONAL SUMMARY			FRC PERFORMANCE SUMMARY			
SNO	Control Variable	Operational Status	SNO	FRC_BUS_LINE	LINE_STATUS	AMPLITUDE
1	FRC Control	Enabled	1	LINE1	Closed	Rated
2	FRC Status	Active	2	LINE2	Closed	Rated
3	FRC Error Status	Error	3	LINE3	Closed	Rated
4	BR1 Control	Enabled	4	LINE4	Closed	Rated
5	BR2 Control	Enabled	5	LINE5	Closed	Rated
6	BR3 Control	Enabled	6	LINE6	Closed	Rated
7	BR4 Control	Enabled	7	LINE7	Closed	Rated
8	BR1 Status	Active	8	LINE8	Closed	Rated
9	BR2 Status	Active	9	LINE9	Closed	Rated
10	BR3 Status	Active	10	LINE10	Closed	Rated
11	BR4 Status	Active	11	LINE11	Closed	Rated
12	BTC2 Status	Untrip	12	LINE12	Closed	Rated
13	BTC3 Status	Untrip				
14	BTC3 Status	Trip				
14	BTC4 Status	Trip				

Table (3): Operational Summary of the FRC.

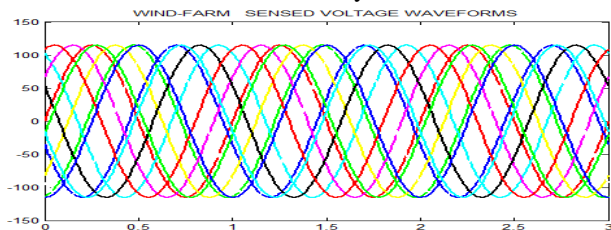
Table (4): Performance Summary of the FRC.



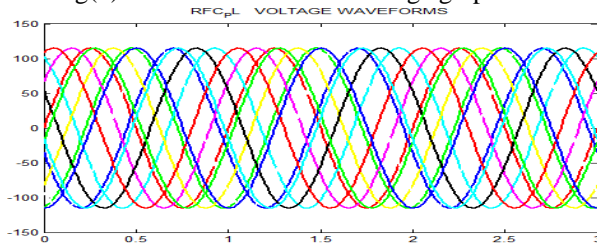
Fig(5): Graphical variation characteristics of breaker control waveforms of the Wind-Farm system.



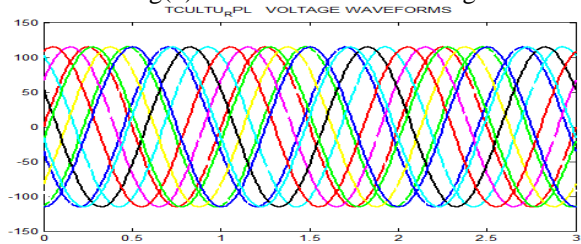
Fig(6): Micro-Grid standard voltage graphs.



Fig(7): Wind-Farm sensed voltage waveforms.



Fig(8): Reactive Flow Cancelled Power Levels.



Fig(9): Restored power levels.

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V. CONCLUSION

The unexpected reactive power flows may cause new threats to the operational conditions of the DMGS and can affect the quality of power being supplied by it. In order to counteract to these reverse power flows and to enable the fault protected[1] and rated quality operation the DMGS in this project we developed a novel algorithm for the stochastic reactive power management in a DMGS using an Adaptive Reactive Power Compensation and Regulation Unit (ARPC&RU) along with its associated control circuitry with renewable Distributed Power Generation Unit(DPGU)s[19]. Generally the reactive power compensation is considered as an ancillary service. The fault protection[1] of the proposed DMGS is performed with an aid of another defensive module called an Fault Regulation Circuit(FRC)[17][18]. Thus the proposed algorithm is designed to perform the fault isolated reactive power compensation in the DG based MGS. Numerical tests on an industrial 12-bus MGS are conducted in the Matlab environment. Simulation results adjudged that the proposed approach is best in all aspects and outperforms all the existing techniques.

VI. FUTURE WORK

In this project in order to reduce the complexity, the proposed approach is practically implemented with 12-line ring bus architecture. But there are no practical constraints on the size of the network and hence it can be extended to any large size DMGS with increased number of operational zones and any higher order bus. Increase in the physical size of the DMGS network doesn't cause any performance dissimilarities and extra limitations. As a consequence the physical size and processing capability of the internal components has to be justified with the proper selection of internal components of matched capacity and efficiency.

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