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IMPACT OF POWER SYSTEM FAULTS ON OUTPUT POWER OF POWER PLANT AND POWER CONSUMPTION OF DYNAMIC LOADS

NAVEEN GAUR[1], OM PRAKASH MAHELA[2] & RAM NIWASH MAHIA[3]

[1]Principal, Aryan Polytechnic College, Ajmer, India

[2]Research Scholar, IIT Jodhpur India, and Assistant Engineer, RRVPNL, Jodhpur, India

[3]Research Scholar, Indian Institute of Technology, Jodhpur, India

ABSTRACT

In power transmission and distribution system, the majority of the voltage and current signal distorsions are caused by faults. These distorsions affect the output power of the generators as well as power consumptions by the loads. This paper presents the study of impact of power system faults on the output power of the power plant and power consumption of dynamic loads. The effect of single-phase to ground fault, double line fault, double line to ground fault, three phase faults involving ground and without ground on power output of plant power and consumption by the dynamic load are presented in detail. The variations of active and reactive power during the faulty conditions and post fault conditions are investigated. A test system having generation, loads, and transmission lines and connected to the utility network is modeled in MATLAB/Simulink environment.

KEYWORDS: Active Power, Dynamic Load, Fault, Power Plant, Reactive Power, Utility Grid

1. INTRODUCTION

Power system network consists of transmission and distribution lines used to transfer electrical power from generating stations to load centres, generators, transformers, capacitors, inductors, and linear/non-linear loads [1]. The power transmission lines and loads in the system are susceptible to faults due to continous exposition to the environment and switching. The single-phase to ground faults are the most frequent to occur on EHV transmission systems and most of the faults are transient in nature induced by lighting [2]. The power system faults affect the performance of transmission lines, loads, power generators, capacitors, inductors and other measuring and protection equipments [3]. The faults produce disturbances in frequency and voltage and any deviation/disturbance manifested in the voltage, current and frequency from the standard rating is treated as a power quality (PQ) problem that results in failure or malfunctioning of electrical/electronic equipments and dynamic loads [4]. The performance of the capacitor banks in the power system is also affected by the faults [5].

The wide study of power system faults have been reported in the literature. A novel technique using wavelet transform for fault detection, classification and location in transmission lines is proposed in [6]. In [7], authors described a transmission line protection scheme with two protection functions: directional zone and fault classification. The proposed technique requires no information from remote ends and uses current measurements of only one phase of the three phase systems for determining the fault direction, the faulted line and the fault type. A novel technique for fault detection and classification in the extremely high voltage transmission line using the fault transients is proposed in [8]. In [9], authors presented a novel morphological un-decimated wavelet decomposition scheme for fault location on power transmission lines. This technique is developed based on morphological wavelet theory for both the extraction of the transient features and noise reduction in signal processing.

This paper presents the study of impact of power system faults on the output power of the power plant and power consumption of dynamic loads. The effect of single phase to ground (LG) fault, double line (LL) fault, double line to ground (LLG) fault, three-phase (LLL) fault without involving ground, and three-phase (LLLG) fault involving ground on the output power of the power plant and active and reactive power consumption by the dynamic load in the presence of capacitors, RL loads, transformers, transmission lines, asynchronous generators used in the wind plants, and connection of the test system with utility grid are discussed and analyzed. The power variation of the power plant and dynamic loads during the faulty conditions and post fault conditions are investigated.

This paper is divided into four sections. Starting with an introduction in section 1, the section 2 covers the test power system model used for the study of impact of power system faults on the output power of the power plant and power consumption of dynamic loads. The simulation results and their discussion are presented in section 3. Finally, the concluding remark is included in the section 4.

2. PROPOSED POWER SYSTEM MODEL

The test system for the analysis of the impact of power system faults on output power of power plant and power consumption of dynamic loads is shown in Figure 1. The test system has four voltage levels of 13.8 kV, 120 kV, 25 kV, and 575 V. The power plant of 150 MVA and 13.8 kV is connected to the bus (B-1). The test system is connected to the utility network at bus B-2. The details of transmission line of length 25 km in the system between buses B-3 and B-4 are given in Table 1. The details of three transformers in the test system are given in Table 2. The loading status of loads L-1 and L-2 is given Table 3. A capacitor of capacity 1.2 MVAR is connected at bus B-5 which is mainly provided for reactive power compensation of the asynchronous generator of 9 MW connected at bus B-5. The system operating frequency is 60 Hz. The measurement of power plant active power output is taken at the output terminals of the power plant. The measurement of the active and reactive power consumption of the dynamic load (L-2) are taken at the terminals of the load.

Table 1: Test System Transmission Line Parameters

S. No.	Attributes	Value
1	Positive sequence resistance R1 (Ω/km)	0.01165
2	Zero sequence resistance R0 (Ω/km)	0.2676
3	Positive sequence inductance L1 (H/km)	0.8679e-3
4	Zero sequence inductance L0 (H/km)	3.008e-3
5	Positive sequence capacitance C1 (F/km)	13.41e-9
6	Zero sequence capacitance C0 (F/km)	8.57e-9

Table 2: Transformer Parameters

Transformer	MVA	kV-High	kV-Low	HV Winding		LV Winding	
				R (pu)	L (pu)	R (pu)	L (pu)
T-1	175	120	13.8	0.002	0.08	0.002	0.08
T-2	50	120	25	0.002	0.06	0.002	0.06
T-3	12.5	25	0.575	8.33e-4	0.025	8.33e-4	0.025

Table 3: Loading Status

Load	Quantity of Load		Remarks
	P (MW)	Q (Mvar)	
L-1	3	1.5	Parallel RL load
L-2	10	3	Dynamic load

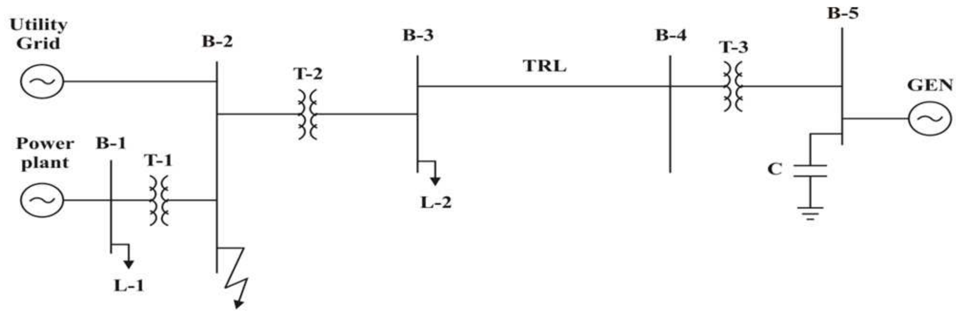

Figure 1: Proposed Model of Power System

3. SIMULATION RESULTS AND DISCUSSION

The power system model shown in Figure 1 is simulated in Matlab/Simulink environment. The faults are created on bus B-2 at 12th cycle and cleared at 18th cycle. The active power output of the power plant and active and reactive power consumption of the dynamic load are plotted for a period of 2 seconds.

3.1. Single-Line to Ground Fault

The single line to ground fault is created on bus B-2 at 12th cycle and cleared at 18th cycle. The results are taken for a period of 2 seconds. The active power output of the power plant is plotted in the Figure 2. The active and reactive power consumption of the dynamic load is plotted in Figure 3. The power output of the plant decrease during the fault and high frequency oscillations are observed. The magnitude of the oscillating transients increases after the clearance of the fault. Power fluctuations are observed after the clearance of the fault and power output becomes constant after a period of the 2 seconds. The active and reactive power consumption of the dynamic load also decreases during the faulty conditions. The power oscillations are also observed in the active and reactive power consumption of the dynamic load after fault clearance. The active power consumption reaches to 10.50 and reactive reaches to the value of 3.25. Slight power variations are observed in the active and reactive power consumption in the load and become constant after clearance of the fault during short duration. Minimum values of active power output of power plant, active and reactive power consumption of dynamic load during LG fault are provided in Table 4.

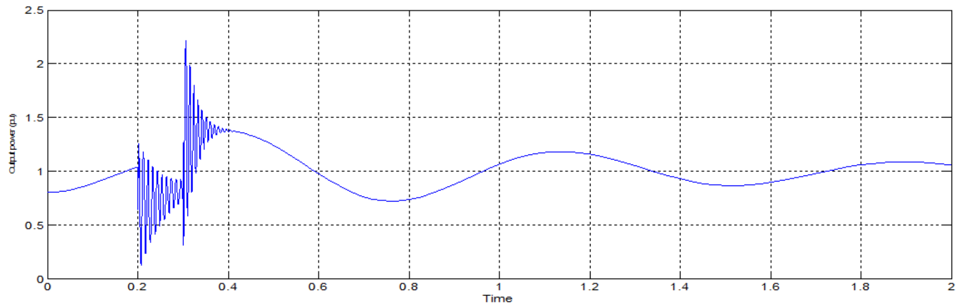

Figure 2: Power Plant Output Power (PU) during LG Fault

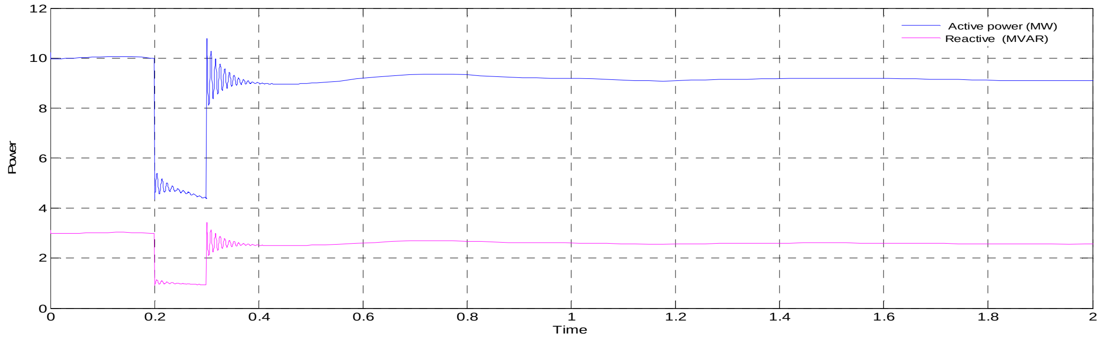

Figure 3: Active and Reactive Power Consumption of Dynamic Load during LL Fault

3.2. Double Line Fault

The double line fault is created on bus B-2 at 12th cycle and cleared at 18th cycle. The results are taken for a period of 2 seconds. The active power output of the power plant is plotted in the Figure 4. The active and reactive power consumption of the dynamic load is plotted in Figure 5. The power output of the plant decrease during the fault and high frequency oscillations are observed. The decrease in the power is high as compared to the LG fault. The magnitude of the oscillating transients increases after the clearance of the fault and reaches to the 2.60. Power fluctuations are observed after the clearance of the fault and output power becomes constant after a period of the 2 seconds. The active and reactive power consumption of the dynamic load also decreases during the faulty conditions. The power oscillations are also observed in the active and reactive power consumption of the dynamic load. The active power reaches to 11 and reactive reaches to the value of 3.75. Slight power variations are observed in the active and reactive power consumption in the load and become constant after clearance of the fault during short duration. Minimum values of active output of power plant, active and reactive power consumption of dynamic load during LL fault are provided in Table 4.

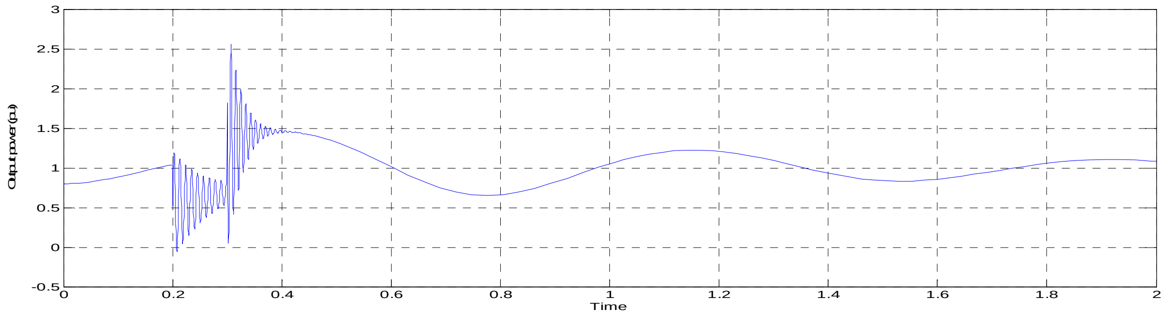

Figure 4: Power Plant Output Power (PU) during LL Fault

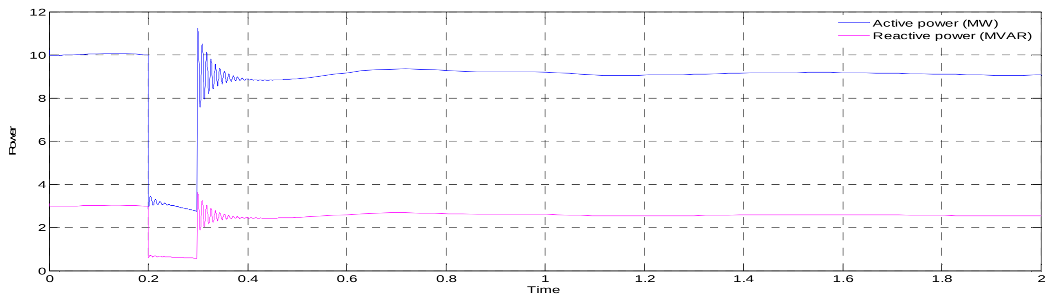

Figure 5: Active and Reactive Power Consumption of Dynamic Load during LL Fault

3.3. Double Line to Ground Fault

The single line to ground fault is created on bus B-2 at 12th cycle and cleared at 18th cycle. The results are taken for a period of 2 seconds. The active power output of the power plant is plotted in the Figure 6. The active and reactive power consumption of the dynamic load is plotted in Figure 7. The power output of the plant decrease during the fault and high frequency oscillations are observed. The magnitude of the oscillating transients increases after the clearance of the fault and reaches to the 3.25. Power fluctuations are observed after the clearance of the fault and power output becomes constant after a period of the 2 seconds. The active and reactive power consumption of the dynamic load also decreases during the faulty conditions. The power oscillations are also observed in the active and reactive power consumption of the dynamic load. The active power reaches to 12 and reactive reaches to the value of 4. Slight power variations are observed in the active and reactive power consumption in the load and become constant after clearance of the fault during short duration. Minimum values of active power output of power plant, active and reactive power consumption of dynamic load during LLG fault are provided in Table 4.

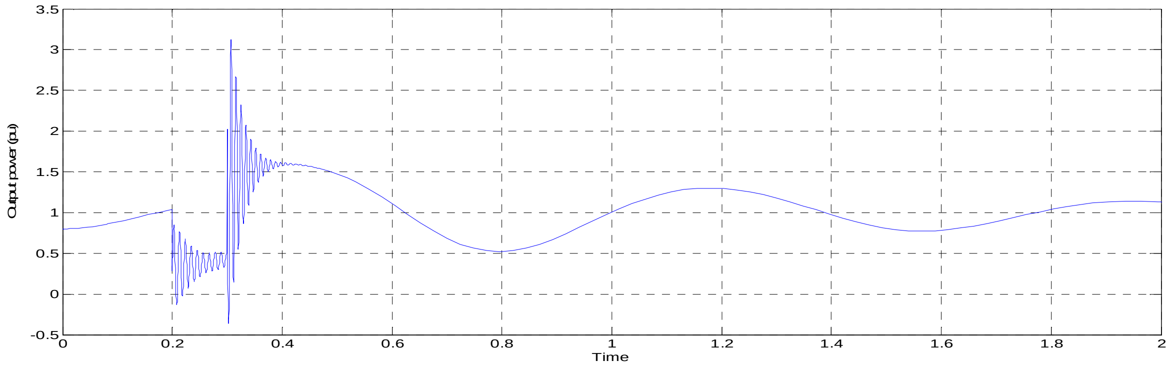

Figure 6: Power Plant Output Power (PU) during LLG Fault

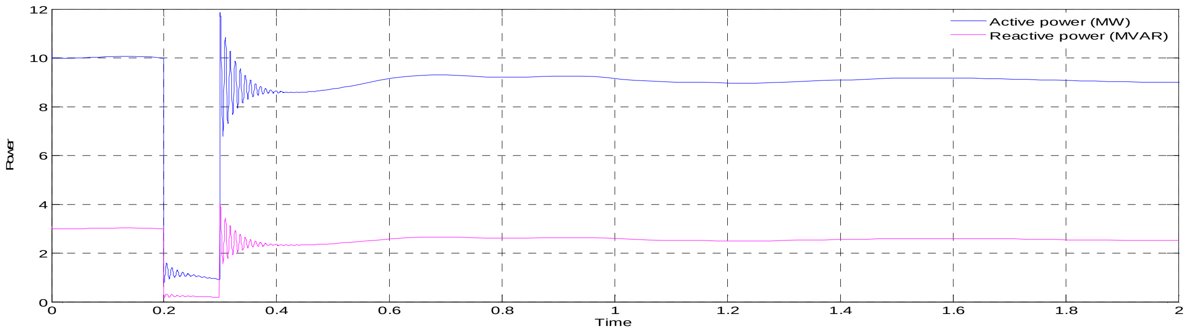

Figure 7: Active and Reactive Power of Dynamic Load during LLG Fault

3.4. Three Phase Fault without Involving Ground

The three phase fault without involving ground (LLL) is created on bus B-2 at 12th cycle and cleared at 18th cycle. The results are taken for a period of 2 seconds. The active power output of the power plant is plotted in the Figure 8. The active and reactive power consumption of the dynamic load is plotted in Figure 9. The power output of the plant decrease during the fault and no significant power oscillations are observed. The magnitude of the oscillating transients increases after the clearance of the fault and reaches to the 4. Power fluctuations are observed after the clearance of the fault and power output becomes constant after a period of the 2 seconds. The active and reactive power consumption of the dynamic load also decreases to zero during the faulty conditions. The power oscillations are also observed in the active and reactive power consumption of the dynamic load after clearance of fault. The active power reaches to 13 and reactive reaches to the value of 4.5. Slight power variations are observed in the active and reactive power consumption in the load and become constant after clearance of the fault during short duration. Minimum values of active output of power plant, active and reactive power consumption of dynamic load during LLL fault are provided in Table 4.

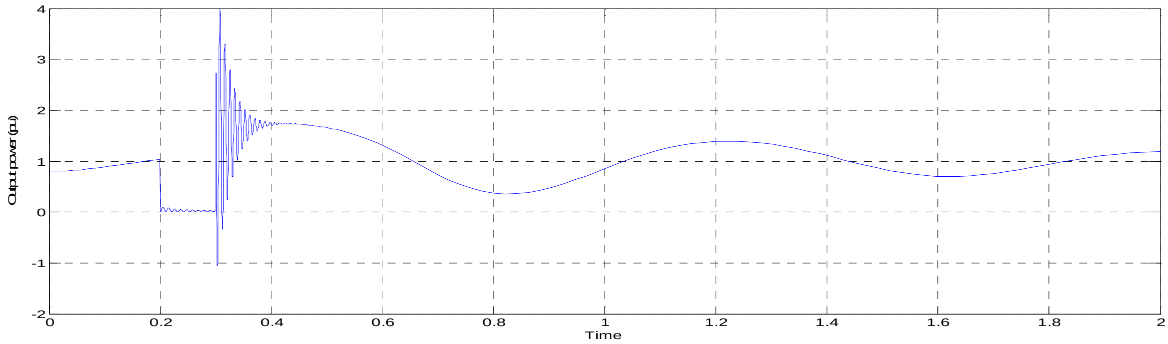

Figure 8: Power Plant Output Power (PU) during LLL Fault

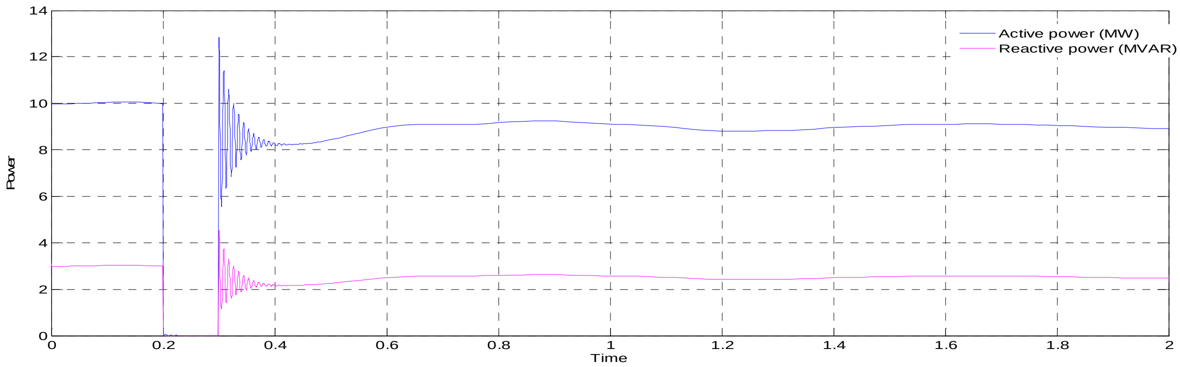

Figure 9: Active and Reactive Power Consumption of Dynamic Load during LLL Fault

3.5. Three Phase Fault Involving Ground

Three phase fault involving ground is created on bus B-2 at 12th cycle and cleared at 18th cycle. The results are taken for a period of 2 seconds. The active power output of the power plant is plotted in the Figure 10. The active and reactive power consumption of the dynamic load is plotted in Figure 11. The power output of the plant decrease during the fault and no significant power oscillations are observed. The magnitude of the oscillating transients increases after the clearance of the fault and reaches to the 4. Power fluctuations are observed after the clearance of the fault and power output becomes constant after a period of the 2 seconds. The active and reactive power consumption of the dynamic load also decreases to zero during the faulty conditions. The power oscillations are also observed in the active and reactive power consumption of the dynamic load after clearance of fault. The active power reaches to 13 and reactive reaches to the value of 4.5. Slight power variations are observed in the active and reactive power consumption in the load and become constant after clearance of the fault during short duration. Minimum values of active output of power plant, active and reactive power consumption of dynamic load during LLG fault are provided in Table 4. The three phase fault conditions involving ground are similar to the conditions of three phase fault without involving the ground.

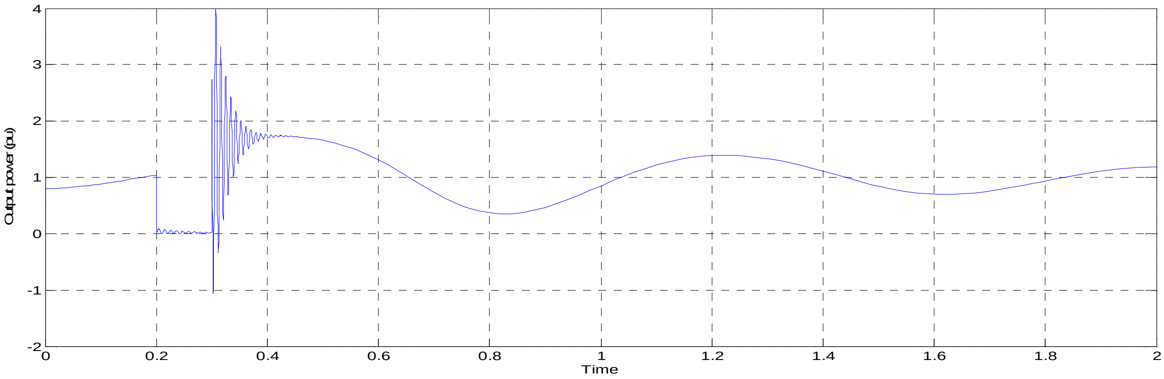

Figure 10: Power Plant Output Power (PU) during LLLG Fault

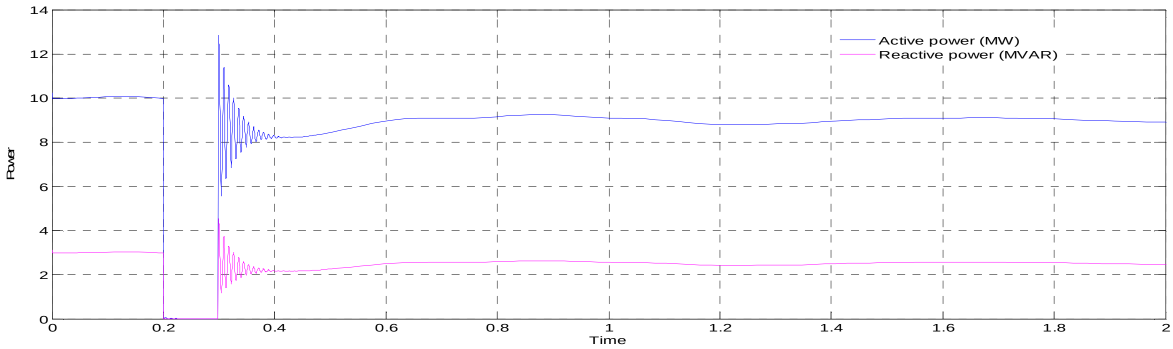

Figure 11: Active and Reactive Power of Dynamic Load during LLLG Fault

Table 4: Minimum Values of Active and Reactive Power

Power	Type of Fault				
	LG	LL	LLG	LLL	LLLG
Active power output of plant (pu)	0.75	0.75	0.5	0	0
Active power consumption of dynamic load (MW)	4.25	3	1	0	0
Reactive power consumption of dynamic load (MVAR)	1	0.25	0.25	0	0

4. CONCLUSIONS

In this paper, the impact of the power system faults on the power output of the power plant and power consumption by the dynamic load is discussed. The analysis is carried out for the impact of LG, LL, LLG, LLL and LLG faults on the power output of the power plant and power consumption by the dynamic load. From the developed study, it can be concluded that during the faulty conditions the power output of the power plant decreases. The effect of LG and LL faults is minimum, where the power output decreases to 0.75 and maximum effect is observed for LLL and LLG fault where the power output reduces to zero. In the conditions of LG, LL and LLG fault, the high frequency power transients are observed during the faulty conditions. The high frequency power transients are observed after the clearance of the fault in all the faulty conditions. The active and reactive power consumption by the dynamic load decreases in all the faulty conditions. The effect is minimum during the LG fault where active power reduces from 10 MW to 4.25 MW and reactive power reduces from 3 MVAR to 1 MVAR. The effect is maximum during LLL and LLG faults where the active and reactive power reduces to zero.

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APPENDICES

Biographies

Naveen Gaur received Engineering Diploma, from Govt. polytechnic college, Ajmer, India in 2000. He received B.E. Electrical from Rajasthan Institute of Engg. and Tech. Jaipur, India in 2004 and M. Tech. (Power System) from Bhagwant University, Ajmer, India, in 2014.

Presently he is working as a Principal at Aryan Polytechnic college, Ajmer, India. He also worked as a Principal at Santosh Adarsh Pvt. ITI, Riya Badi, Nagaur, since July-2013 to Aug-14 and also worked as a Lecturer at Aryan Polytechnic college, Ajmer From Oct-2011 to July-2013. His research interest includes the power system and power electronics. He is author of 3 international journal research papers.

Ram Niwash Mahia received his B.E. degree in Electronics instrumentation and Control Engineering from Govt. Engineering College Bikaner, Bikaner, India and his M.E. degree in Control and Instrumentation under Electrical Department from Delhi College of Engineering, Delhi, India in 2007 and 2009, respectively. He is pursuing Ph.D. degree in Information Communication and Technology from Indian Institute of Technology Jodhpur, Rajasthan, India, since August-2011. From March 2010 to july-2011, he was an Assistant Professor with the Department of Electronics Instrumentation and Control Engineering, Global Institute of Technology, Jaipur, Rajasthan, India. His research interests include control of multi-agent systems, nonlinear control, robust control and its applications for uncertain systems.

Om Prakash Mahela was born in Sabalpura (Kuchaman City) in the Rajasthan state of India, on April 11, 1977. He studied at Govt. College of Engineering and Technology (CTAE), Udaipur, and received the electrical engineering degree from Maharana Pratap University of Agriculture and Technology (MPUAT), Udaipur, India in 2002. He received M. Tech. in 2013. He is currently pursuing PhD from Indian Institute of Technology, Jodhpur, India.

From 2002 to 2004, he was Assistant Professor with the RIET, Jaipur. From 2004 to 2013, he has been Junior Engineer-I with the Rajasthan Rajya Vidhyut Prasaran Nigam Ltd. (RRVPNL), India. Presently he has been Assistant Engineer with RRVPNL. His special fields of interest are Transmission and Distribution (T&D) grid operations, Power Electronics, Power Quality, Renewable energy sources and Load Forecasting. He is an author of 23 International Journals and 15 Conference papers. He is a Member of IEEE. He is Member of IEEE Power & Energy Society. Mr. Mahela is recipient of University Rank certificate from MPUAT, Udaipur, India, in 2002 and Gold Medal for M. Tech. in 2013.