POWER GRID RESTORATION OPTIMIZATION CONSIDERING GENERATING PLANT ISLANDING SCHEME

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ABSTRACT

The restoration process of the bulk-power transmission system following a partial or a total blackout, have two main issues during a restoration, those are voltage control and frequency control. Special attention is therefore given to the behaviour of network parameters, control equipments as they affect the voltage and frequency regulation during the restoration process. During restoration due to wide fluctuations in the frequency and voltage it becomes very difficult to maintain the integrity in the system. Inability to control the frequency may lead to unsuccessful restoration. Repeated collapse of the system islands due to tripping of generators either due to over frequency or under frequency causes delay in getting normalcy. The paper considers aspects of computer application in restoration and Islanding in context of Maharashtra State power system. During conditions of blackout, the process of Islanding can satisfy the power requirements for a particular area, thus assisting the grid operator as well as helping in reducing the time required for the complex restoration processes. The main obstacle in the process of restoration or islanding is number of switchgears located at various locations with different configurations.

I. INTRODUCTION

Large interconnected power systems may be seriously affected by severe occurrences that could lead to a cascade of automatic actions. These types of events may be the source of an uncontrolled network splitting with harmful effects on power quality to end-users. In highly stressed operating conditions, a cascade outage may eventually conduct to a partial or complete blackout. The power systems operated by the utilities in developing countries suffer from a large gap between demand and generation, inadequate transmission capacity, and nonuniform location of the load centers and generating stations. In most of the cases, occurrences of faults in such systems end up with the worst consequence, which is complete blackout. Uninterrupted power supply is essential for the national productivity and social structure and hence system must be made flawless at any cost. After occurrence of severe system disturbances, the system may split into parts, which may or may not survive depending on the load generation balance. The part system containing the generation sources and certain loads, which are planned to be separated from the main grid during system disturbance at preconceived points either through under frequency and / or directional power relays are called 'Islands'. During restoration due to wide fluctuations in the frequency it becomes very difficult to maintain the load-generation balance. Inability to control the frequency may lead to unsuccessful restoration. Repeated collapse of the system islands due to tripping of generators either due to over frequency or under frequency causes delay in getting normalcy. The restorative procedure is the operation of the power system equipments but with portions of the load not being served and / or with loss of system integrity [1]. In the present Islanding and restoration systems, concentration is only on the Islands and not on the restoration procedure that is, posts Islanding conditions. The grid requires power pool for restoration and the power pool can be any islanded system, separated from the main grid at pre determined points.

II. MAHARASHTRA STATE POWER SYSTEM

The western region of Indian Power Grid consists of Maharashtra State power system, with highest installed generating capacity of around 15,000 MW (as on 31/03/2005), along with Gujrat, Madhya Pradesh, Chattisgad, and Goa. Some private players also play a power game in hands with state electricity Generation Company. The wide electrical power grid also supports the system. The figure below indicates the 400 kV power system network in Maharashtra State with major transmission lines. The major hydroelectric power station, Koyna situated in Western Maharashtra has total installed capacity of 1960 MW. Power generation of Dabhol Power Corporation (DPC) of 728 MW is not available since 29th

May 2001. The major generating stations are located in Eastern Maharashtra i.e. at Koradi (1080 MW), Chandrapur (2340 MW), Khaparkheda (840 MW) and Bhusawal (478 MW).

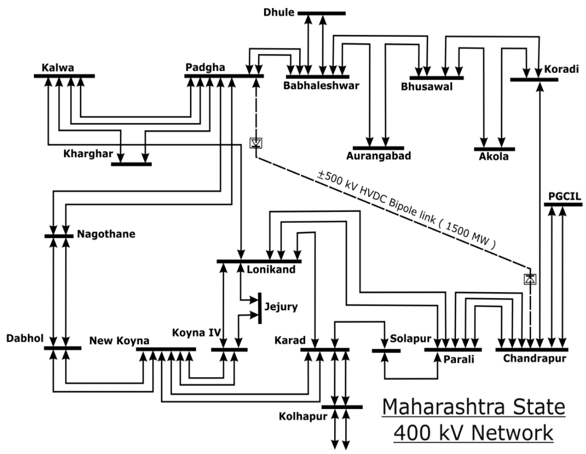

Figure 1: Maharashtra State power system network

The load centres are mainly around Mumbai and Pune regions situated in Western Maharashtra. The distance between generating station and major load centres is of the order of 800 to 900 circuit kilometres. For evacuating power from Eastern Maharashtra to Western Maharashtra there are + 500 kV HVDC bipolar line, five 400 kV lines and associated 220 / 132 kV networks in the state. The Western part of the state excluding the small area near Mumbai is monitored from SLDC (State Load Dispatch Centre) at Kalwa. The Eastern part comprising of Vidarbh, Khandesh and Marathwada region is monitored by ALDC (Area Load Dispatch Centre) at Ambazari near Nagpur. Both the Load Dispatch Centres are equipped with R-30 computer system. This system provides the Supervisory Control and Data Acquisition System (SCADA) functions. SLDC at Kalwa and ALDC at Ambazari are equipped with time synchronization using G.P.S. signals.

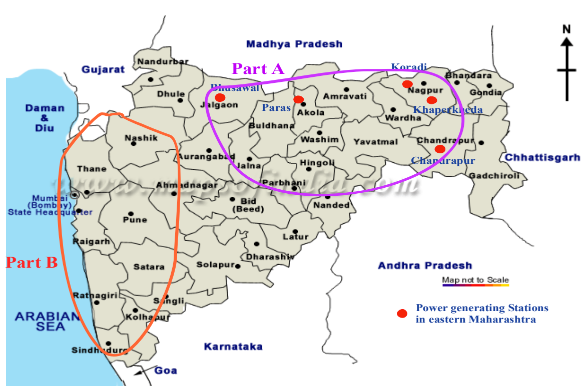

Figure 2: Maharashtra State power system splitting

The major power generating stations in the state are directly connected with the other parts of the state with 400 kV transmission line, which is an added advantage for the above system.

But the power system is divided in two regions, one with higher generating capacity but less load consumers that is, eastern part of Maharashtra State (indicated by 'part A' in below figure) and second is less generators but maximum load consumption i.e. western part of the state (indicated by 'part B' in figure 2). The state power system splitting in two parts may generally lid to a grid failure in the state due to frequency mismatch. The number of consumers supplied by State Electricity Distribution Company (DISCOM) is indicated in the below table.

TABLE: 1 classification of consumers

Sr. No.	Type of Consumer	No. of Consumers (in Lakhs) for year 2005 – 06
01	Domestic / Residential	98.55
02	Commercial	11.02
03	Irrigation	22.97
04	Other	04.02
	Total	**136.56**

(Source: MAHADISCOM website)

III. ISLANDING SCENARIO

The Islanding scheme is presently in operation in the state for Mumbai region with Reliance (REL) and Tata (TEC), the private players. For rest of the Maharashtra State, generating station wise (or generator wise) islanding may be a hopeful solution to avoid complete blackout for the consumers. In this paper the stress is given to the Islanding which will be helpful not only for the interruption free power supply to the consumers but also for the system restoration. This Islanding system is designed for six different sectors in the Maharashtra State which are consisting of generation, one sector without generation, so in this way seven sectors are considered. The figure below (figure: 3) illustrates the seven sectors along with existing Islanding i.e. Mumbai with existing transmission lines.

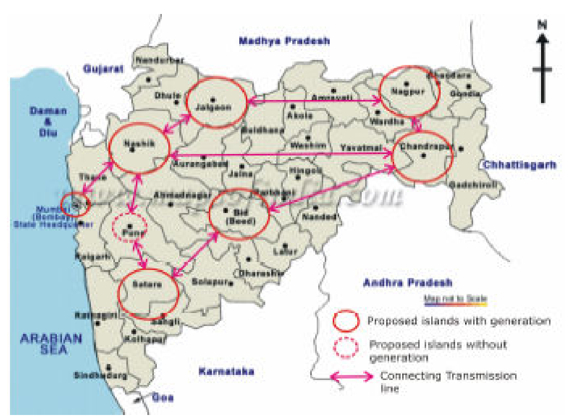

Figure 3: Proposed Islands supporting restoration system in Maharashtra State (India)

IV. THE PRESENT POWER SYSTEM RESTORATION TECHNIQUES AND THEIR LIMITATIONS

The three main Power System Restoration (PSR) techniques recently proposed to solve the limitations of the pre-established guidelines were implemented based on the Cooperative Restoration Principle. Following are the three PSR techniques [2 to 10].

1. Mathematical Programming Techniques for PSR
2. Knowledge based Techniques for PSR
3. Petri Nets in PSR.

As it is known that necessary time and the capability of finding restoration plans under unseen restoration scenarios plays a critical role in PSR estimation [11]. Using these techniques as evaluation methods, it can be said that the techniques have limitations. The main problem with these techniques is the time required to find the restoration plan [2, 12, 13]. The rule-based technique usually takes several minutes to find the plan, mainly because the number of rules is proportional to the size of the system. In this way, in bigger transmission systems where all restoration possibilities must be covered, the number of production rules increases significantly, which diminishes the technique's speed considerably. The mathematical programming and the Petri Net approach have similar performance characteristics. In both cases a certain search algorithm has to be applied in order to determine the restoration plan. The fastest search algorithm, the depth-first search, doesn't guarantee an optimum solution and its performance depends upon the size of the state space. In large transmission systems, where the size of the state space increases, the search process will take a longer processing time, time that could increase even more if a load flow is needed after each state is obtained to check the state's feasibility. Due to limitations of the said methods the use of new proposed method, which is restoration with the support of small islands in the system will indeed help to improve the performance of the grid controller.

V. PROBLEM DEFINITION

The paper aims at finding out the possibility and power system feasibility of PSR, supported by islands with all possible ways available and suitable. This technique is different from the others stated earlier. In this technique the system will be designed in such a way that on pre decided points or parameters, the small part of the system will get separated and the same will provide power pockets to the 'grid controller' to integrate the grid by connecting tie lines. The project will be a set of following:

1. Goals for the system islanding
2. Maintenance of the formed islands
3. Hierarchy of operations for integration of grid
4. Load flow of the said system
5. Maintenance of total integrated grid

In the paper, more light is put on the issue that is concerned not only with restoration, but the restoration with the help of small Islands available in the network. These Islands help the grid operator by providing generation within the network area as well as it also provides load pockets which are indeed necessary at the time of restoration to reduce the restoration time.

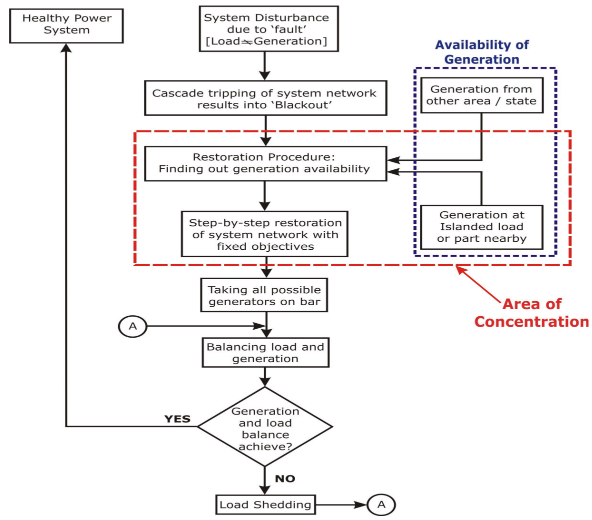

Figure 4: Problem flow chart

So, the paper considers aspects of both restoration and Islanding. During conditions of blackout, the process of Islanding can satisfy the power requirements for a particular area, thus assisting the grid operator as well as in helping to reduce the time required for the complex restoration processes. The preliminary flow chart for problem understanding is shown below in figure (Figure: 4, Problem flow chart). The proposed restoration scheme applies the parallel restoration technique. In this technique the electric system is divided into a number of isolated islands that will be restored in parallel. These islands will remain electrically isolated from each other until each island is completely restored and stable. After the islands are restored, the tie-lines are closed. The restoration scheme uses pre and post disturbance data to generate the power system restoration plans for each island. In this research paper, the restoration load pattern is assumed to be equal to the pre disturbance load.

VI. CASE STUDY

A case study for the Power System Restoration (PSR) technique, which is mentioned in the paper, was studied for one model sector. This was considered for Nasik Thermal Power Station (NTPS) which is near to Nasik city. This power station is situated in western side (Part B in figure: 2) in Maharashtra State. NTPS feeds power to Nasik city and surrounding industrial and rural area via Grid Control Room (GCR) and Old Control Room (OCR) substations present in power station premises. The OCR substation is connected with NTPS stage – I (2X140 MW) via two 150 MVA generator transformers and also connected with 220 kV double circuit interstate Nasik – Navsari (Gujrat State) line. The GCR substation is connected with NTPS stage – II (3X210 MW) via three 150 MVA transformers and also connected to Vaitarna (60 MW) and Bhandardara (12.5 MW + 34 MW), two hydro power generating stations via 132 kV Igatpuri – I and II feeders. The GCR and OCR substations are connected to each other via 220 kV and 132 kV bus. One common load, which is Sinner city including Sinner MIDC (Industrial Area) and L & T Company, is also fed by both substations. This load is ideal for islanding operation since its maximum power demand is around 80 to 90 MW which is near to the capacity of one of the generating sets of NTPS in stage – I. The figure 6 shows the details about the case study of NTPS Islanding outline. In the worst situation of grid disturbance, the outgoing feeders from GCR and OCR substation except the Sinner feeders may be tripped with df / dt relay, according to table: 2, to ensure the Islanding for one of the generators. The 132kV feeders are mostly rural and agricultural feeders. The 220 kV feeders are grid feeders connected to the state grid or interstate grid (for Navsari feeder only). With the above schedule of feeder closing, the temporary frequency swinging and grid failure can be taken care of. The first schedule will be implemented to save all generating sets in NTPS but with second schedule the desired one can be kept running to supply a particular load like Sinnar. The load power variation can be maintained constant by regulating residential load feeders at Sinnar substation and asking industrial consumers and L & T Company to put the base load on feeders.

TABLE: 2 NTPS outgoing feeder shutdown schedule

Sr. No.	Name of feeders to be closed	Frequency and time duration
01	Manmand, Dindori, Vasala, Kalwan, Chalisgaon and Pimparkhed (all are local 132 kV feeders)	47.7 HZ and 0.2 Sec.
02	Babhleshwar, Navsari, Padgha (all are 220 kV feeders)	47.55 HZ and 0.3 Sec.

The only problem for Islanding is with the number of switchgears present in the circuit. The synchronous operation of the same will decide the actual islanding operation, failure in which will lead to unsuccessful Islanding for the sector. The human mistake of undisciplined operation by the substation operator also plays an important role for restoration process.

VII. SIMULATION AND RESUTS

The above mentioned system was tested for voltage profile using MATLAB. The figure 6 shows the tested model along with the part to be islanded. Figure 7 shows the voltage profile across the load obtained against time and the variation was observed within permissible range of + 5% of rated voltage. The breaker trip signal was supplied at t = 1 sec. Figure 8 shows instantaneous distorted voltage across the breaker which subsequently settled down. The current flowing through the breaker was also plotted against time. As shown in figure 9, it was interrupted at t = 1 sec. The actual test values are added in appendix.

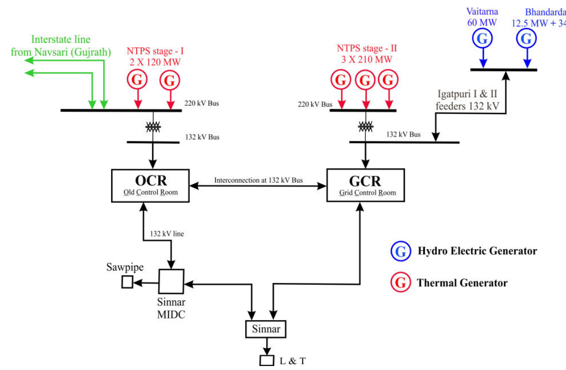

Figure 5: NTPS outline for Islanding

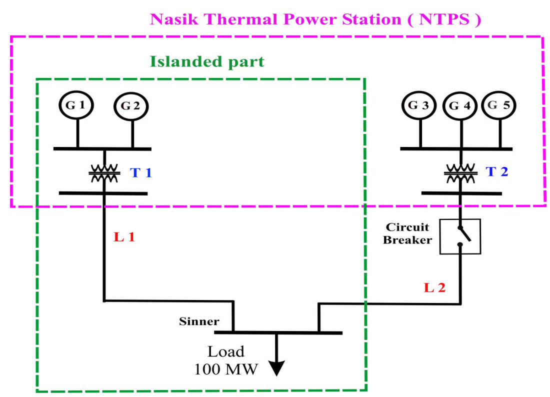

Figure 6: NTPS Islanding test model

VIII. Restoration

After successful islanding of NTPS generating set(s), other part of the grid can be restore by following pathway. The figure 10 indicates the pathway for restoration. Depending on the availability, the grid load can be released.

IX. CONCLUSION AND FUTURE WORK

The main aim of the paper is to put more light on the understanding of the new concept. This scheme is very helpful for a big power system as in Maharashtra state. In normal hierarchy, at the time of grid failure, the power required to start restoration (generally power for thermal power plants to run auxiliaries) is demanded from the states where power is available. This of course includes money and time matters. This can be avoided by using the proposed scheme. As mentioned earlier the present restoration methodologies have time constrains to implement. So this new scheme will definitely help to reduce restoration time and save the state from total blackout. The system study can be considered as a future study for mini and micro islands to strengthen the power system grid.

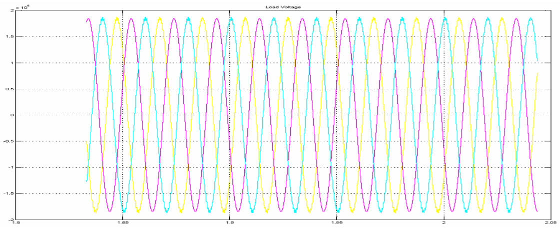

Figure 7: Voltage profile across load

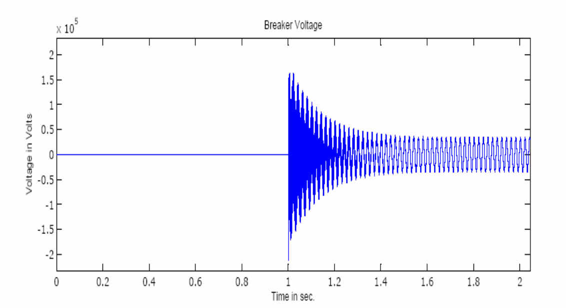

Figure 8: Voltage across the breaker

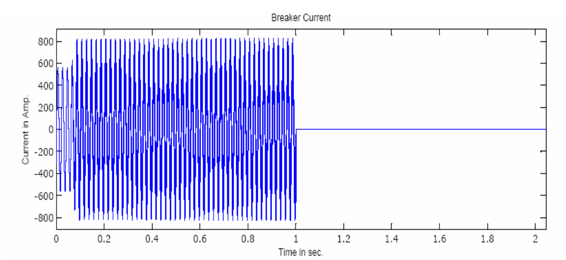

Figure 9: Current flowing through the breaker

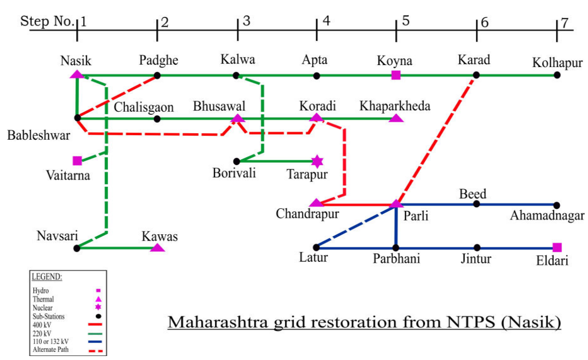

Figure 10: Restoration path from NTPS

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APPENDIX

Table 3: Transformer Data

Transformer	MVA	R_T	X_T	Tap
T 1	100	0.0007	0.0138	1.0
T 2	150	0.0007	0.0142	1.0

Table 4: Machine Data

Gen No.	R_a	X_d
G 1	0.0	0.2950
G 2	0.0	0.0200
G 3	0.0	0.2495
G 4	0.0	0.3300
G 5	0.0	0.2620

Table 5: Line Data

Line	R_L	X_L	Length
L 1	0.0013	0.0173	80 Kms.
L 2	0.0007	0.0082	80 Kms.

Table 6: Results

Sr. No.	Parameter	Value	Remark
1.	Line voltage	132 kV (rms)	Source voltage
2.	Line voltage	131.85 kV (rms)	Load voltage