CONTINGENCY ANALYSIS AND RANKING ON 400 KV KARNATAKA NETWORK BY USING MIPOWER

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Abstract - *Voltage instability is the phenomena associated with heavily loaded power systems. It is normally intensified due to large disturbance. Power system security and contingency analysis are important tasks in modern energy management systems. The Power system security is one of the significant aspects, where the proper action needs to be taken for the unseen contingency. In the event of contingency, the most serious threat to operation and control of power system is insecurity. Therefore, the contingency analysis is a key for the power system security. The contingency ranking using the performance index is a method for the line outages in a power system, which ranks the highest performance index line first and proceeds in a descending manner based on the calculated PI for all the line outages. This helps to take the prior action to keep the system secure. In this paper Fast Decoupled power flow method is used for the power system contingency ranking for the line outage based on the Active power and Voltage performance index. The ranking is given by considering the overall performance index, which is the summation of Active power and voltage performance index. The proposed method is implemented on 400kV Karnataka Power Transmission Network by using MiPower tool.*

Key Words: **Contingency Analysis, Load Flow, Performance Index, Contingency Ranking, Line outage**

1. INTRODUCTION

Power system engineering is the special branch of electrical engineering, which concerns itself with the technique of generation, transmission and distribution of electrical power. Electrical energy is an essential ingredient for the industrial and all round development of any country. Further it can be adapted easily and efficiently to domestic and industrial applications. Modern power system have grown larger and spread over larger geographical area with many interconnections between neighbouring systems. So optimal planning operation and control of large scale systems require advanced techniques.

To achieve high degree of reliability and economy, problem of planning and coordinated operation of a vast and complex power network have to be solved. This is the main intention of power system studies. For planning the operation, improvement and expansion of power system, a power system engineer needs load flow studies, short circuit studies and stability studies. Besides economical in operation, a power system should be operationally secure. An important part of security study therefore, moves around the power systems ability to withstand the effects of contingencies.

1.1 SYSTEM STATE CLASSIFICATIONS

A formal classification of power system security levels was first suggested by DyLiacco and further clarified by Fink and Carlson in order to define relevant EMS functions. Stott and his team have also presented a more practical static security level diagram as show in the Fig. 1.1, by incorporating correctively secure (Level 2) and correctable emergency (Level 4) security levels. In the Fig. 1.1, arrowed lines represent involuntary transitions between Levels 1 to 5 due to contingencies. The removal of violations from Level 4 normally requires EMS directed "corrective rescheduling" or "remedial action" bringing the system to Level 3, from where it can return to either Level 1 or 2 by further EMS, directed "preventive rescheduling" depending upon the desired operational security objectives.

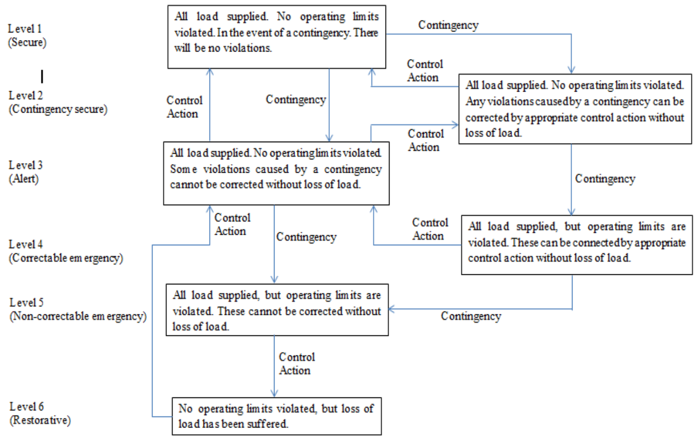

Fig. 1: Power System static security levels

1.2 SECURITY ANALYSIS

The static security level of a power system is characterised by the presence or otherwise of emergency operating conditions (limit violations) in its actual (pre-contingency) or potential (post-contingency) operating states. System security assessment is the process by which any such violations are detected.

The total number of contingency constraints impose on security constrained optimal power flow (SCO) is enormous.

The SCO or contingency constrained OPF problem is solved with or without first optimizing with respect to the base case (pre-contingency) constraints. The general procedure adopted is as follows:

(i) Contingency analysis is carried out and cases with violations or near violations are identified.

(ii) The SCO problem is solved.

(iii) The rescheduling in Step 1 might have created new violations, and therefore it should be repeated till no violations exist.

1.3 OBJECTIVE

The main objective of this paper is to present the contingency analysis and ranking for the 400kV KPTCL network of Karnataka using Fast Decoupled Load Flow method by using MiPower tool.

2. CONTINGENCY ANALYSIS

Contingency Analysis (CA) is a "what if" scenario simulator that evaluates, provides and prioritizes the impacts on an electric power system when problems occur. A contingency is the loss or failure of a small part of the power system (e.g. a transmission line), or the loss/failure of individual equipment such as a generator or transformer. This is also called an unplanned "outage". Contingency analysis is a computer application that uses a simulated model of the power system, to evaluate the effects, and calculate any overloads, resulting from each outage event. Contingency analysis as an inherent function of system security assessment is critical for detecting underlying problems in a power system. Effective power system operation requires power system engineers and operators to analyse vast amounts of information. Among them of particular interest are results of contingency analysis, which is critical in many cases such as security assessment.

The contingency analysis for a considered power system model involves the simulation of individual contingency. In order to make the contingency analysis easier, it comprises of three basic steps. They are as follows:

1) Contingency creation: It is the first step of analysis. It consists of all set of possible contingencies that may occur in a power system. This process comprises of creating contingencies lists.

2) Contingency selection: It is the second step and it is the process which involves selection of severe contingencies from the list that may lead to bus voltage and power limit violations. Here in this process contingency list is minimized by elimination of least severe contingency and taking into account of most severe ones. The severity of contingencies is found by index calculation for this process.

3) Contingency evaluation: It is the third step and the most important one as it involves necessary control action and necessary security actions which are needed in order to mitigate the effects of most severe contingencies in a power system. Performance index (PI) is the method which is used for quantifying the severity and ranking those contingencies in the order of their severity.

The contingency analysis is based on the computations of voltage performance and overload performance indices.

I. Voltage Performance Index:

The voltage performance index PIV is computed as

$$PI_V = \sum_{i=1}^{nb} W_i \left[\frac{|Vi|new - |Vi|spec}{\Delta Vimax}\right]^2$$

Where,

n_b: Number of buses

W_i: Weightage factor for bus i

$|V_i|$ new: Post outage voltage magnitude at bus i

$|V_i|$ spec: Specified voltage magnitude at bus I (1.0 p.u.)

V_{imax}: Maximum allowable voltage change, which is computed as the difference between maximum voltage and specified voltage, if the voltage magnitude is greater than the specified voltage and difference between minimum voltage and specified voltage, if the voltage magnitude is less than the specified voltage. The significance of the weightage is to give lower ranking (higher severity) for poor voltage at specific buses.

II. Overload Performance Index

The overload performance index PIP is evaluated as

$$PI_P = \sum_{i=1}^{nl} W_i \left[\frac{Pinew}{Pilimit}\right]^2$$

Where,

n_l: Total number of series equipment

W_i: Weightage factor for series element i

P_{inew}: New real power flow in the line

P_{ilimit}: Real power flow limit of the line

The contingency can be ranked depending on the importance of a line. If it is desired not to overload a particular line, then that line weightage is assigned a high value.

3. CONTINGENCY RANKING APPROACH

The Contingency Analysis with the utilization of AC power flow gives the point of interest that it gives power flows as far as MW, MVAR and bus voltage sizes. Utilizing the AC power flow over-loads and exact voltage limit infringement. In the present work, for the contingency ranking blackouts of every line has been considered. Performance Indices (PI) are considered for ranking the seriousness of a specific contingency. Fast Decoupled Load flow technique is utilized as a part of computing the lists in a disconnected from the net mode. In the wake of acquiring the qualities got utilizing ordinary strategy are sorted out in dropping way and the most astounding estimation of PI is positioned first.

4. ALGORITHM FOR CONTINGENCY ANALYSIS USING FAST DECOUPLED METHOD

The algorithm for contingency analysis using Fast Decoupled load flow solution is as follows:

Step 1: Read the given system's line data and bus data.

Step 2: Without considering the line contingency perform the load flow analysis for base case.

Step 3: Simulating a line outage or line contingency, i.e. removing a line and proceeding to the next step.

Step 4: Load flow analysis is done for this particular outage, and then calculation of the active power flow is done in the remaining lines and value Pmax is found out.

Step 5: The active power performance index (PIP) is found, which indicates the active power limit violation of the system model taken.

Step 6: Subsequently for the particular line contingency, voltages of all load buses are calculated.

Step 7: Then voltage performance index (PIV) is being calculated which indicates the voltage limit violation at all the load buses due to the line contingencies.

Step 8: Computation of overall performance index is done by adding PIP and PIV for each line outage of the system.

Step 9: Steps 3 to 8 for all line outages is repeated to obtain the PIP and PIV for all the line outages.

Step 10: Then contingencies is ranked based on the overall performance index which is calculate according to the values of the performance indices obtained.

Step 11: Do the power flow analysis for the most sever contingency case and obtain the results.

4.1. FLOW CHART OF THE ALGORITHM

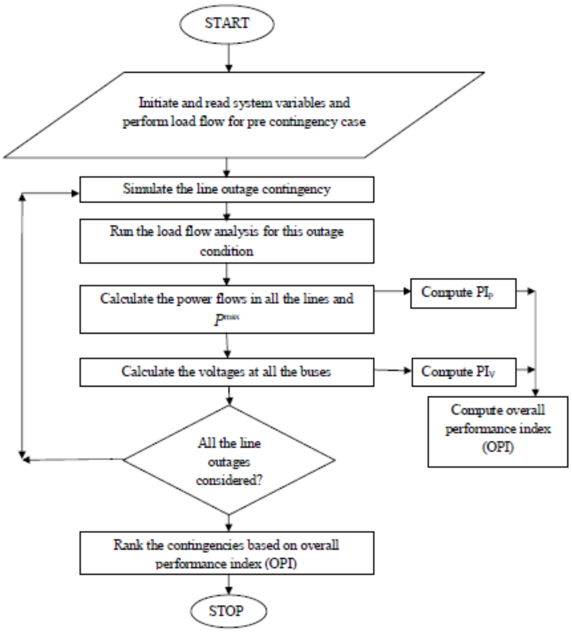

Fig. 2: Flow chart of the Algorithm

5. RESULT

N-1 CONTINGENCY RESULT

The system consists of 1 slack bus, 6 load buses and 6 generator buses. The active power flow in each transmission lines that has been obtained using Fast Decoupled Load Flow. This state of the system corresponds to the pre contingency state. The system has a total 43 number of transmission lines; hence it is evaluated for 43 line contingency scenarios by considering the one line outage contingency at a time.

The voltage performance index is summarized in the Table 1. From Table 1 it can be inferred that outage in line number 38 is the most vulnerable one and its outage will result a great impact on the whole system. The high value of PIV for this outage also suggests that the highest attention be given for this line during the operation. Fig. 3 shows the graphical representation of the voltage performance index for all the line contingencies with the value of PIV on the y-axis and the outage line number labelled on the x-axis.

The active power performance index is summarized in the Table 2. From Table 2 it can be inferred that outage in line number 11 is the most vulnerable one and its outage will result a great impact on the whole system. The high value of PIP for this outage also suggests that the highest attention be given for this line during the operation. Fig. 4 shows the graphical representation of the active power performance index for all the line contingencies with the value of PI on the y-axis and the outage line number labelled on the x-axis.

Table 1: Voltage Performance Index and Contingency Ranking using Fast Decoupled Load Flow for 400 kV KPTCL network (N–1 Contingency)

From	Name	To	Name	PIV	PI_V Rank
1	KAIGA	2	NARENDRA	10.38	11
3	GUTTUR	1	KAIGA	10.22	13
3	GUTTUR	1	KAIGA	10.22	13
3	GUTTUR	2	NARENDRA	9.512	21
3	GUTTUR	2	NARENDRA	9.512	20
3	GUTTUR	4	GD HALLI	9.296	23
3	GUTTUR	5	JSW	10.41	9
3	GUTTUR	6	HIRIYUR	9.033	26
3	GUTTUR	6	HIRIYUR	9.033	27
7	UPCL	8	SHANTHIGRAMA	8.7	29
7	UPCL	8	SHANTHIGRAMA	8.7	30
9	TALAGUPPA	8	SHANTHIGRAMA	7.372	34
10	NELAMANGALA	9	TALAGUPPA	5.776	39
10	NELAMANGALA	8	SHANTHIGRAMA	7.852	33
10	NELAMANGALA	6	HIRIYUR	6.406	36
10	NELAMANGALA	6	HIRIYUR	6.406	37
10	NELAMANGALA	11	BASTIPURA	7.873	31
10	NELAMANGALA	11	BASTIPURA	7.861	32
10	NELAMANGALA	12	HOODY	9.034	25
10	NELAMANGALA	12	HOODY	9.034	24
10	NELAMANGALA	13	BIDADI	9.435	22
10	NELAMANGALA	13	BIDADI	9.435	22
13	BIDADI	14	SOMANAHALLI	9.719	17
13	BIDADI	14	SOMANAHALLI	9.719	18
10	NELAMANGALA	16	GOOTY	6.425	35
12	HOODY	15	KOLAR	10.35	12
12	HOODY	15	KOLAR	10.35	12
12	HOODY	16	GOOTY	6.272	38
5	JSW	18	BTPS	8.964	28
17	RTPS	18	BTPS	9.641	19

17	RTPS	16	GOOTY	10.02	14
17	RTPS	16	GOOTY	10.02	14
17	RTPS	4	GD HALLI	10.7	8
18	BTPS	6	HIRIYUR	9.883	15
18	BTPS	6	HIRIYUR	9.883	16
19	DUMMY19	17	RTPS	46.41	6
20	DUMMY20	17	RTPS	19.27	7
11	BASTIPURA	21	DUMMY21	409.1	1
11	BASTIUPRA	22	DUMMY22	409.1	2
15	KOLAR	23	DUMMY23	406.2	4
15	KOLAR	24	DUMMY24	407.8	3
17	RTPS	40	MEHABOOBNAGAR	405.3	5
1	KAIGA	2	NARENDRA	10.38	10

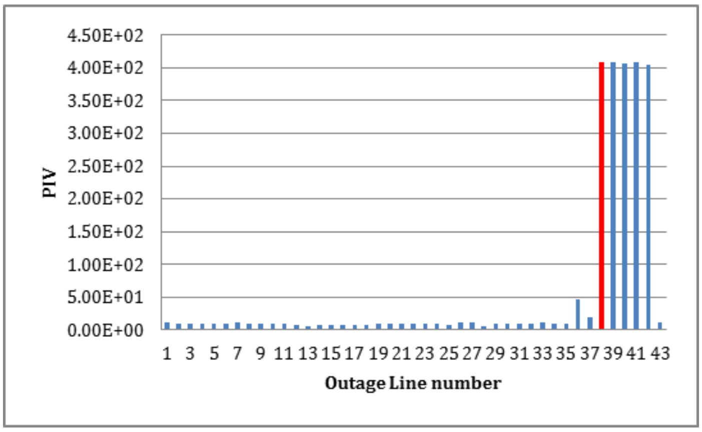

Fig. 3: Value of PIV for 400kV Karnataka Network (N–1 Contingency)

Table 2: Active Power Performance Index and Contingency Ranking using Fast Decoupled Load Flow for 400 kV KPTCL network (N–1 Contingency)

From	Name	To	Name	PIP	PI_P Rank
1	KAIGA	2	NARENDRA	11.18	29
3	GUTTUR	1	KAIGA	11.18	26
3	GUTTUR	1	KAIGA	11.18	26
3	GUTTUR	2	NARENDRA	11.17	33
3	GUTTUR	2	NARENDRA	11.17	32
3	GUTTUR	4	GD HALLI	11.12	34
3	GUTTUR	5	JSW	12.13	7
3	GUTTUR	6	HIRIYUR	11.29	20
3	GUTTUR	6	HIRIYUR	11.29	21
7	UPCL	8	SHANTHIGRAMA	14.69	2
7	UPCL	8	SHANTHIGRAMA	14.69	1
9	TALAGUPPA	8	SHANTHIGRAMA	11.49	15
10	NELAMANGALA	9	TALAGUPPA	11.48	16
10	NELAMANGALA	8	SHANTHIGRAMA	12.98	5
10	NELAMANGALA	6	HIRIYUR	11.88	10
10	NELAMANGALA	6	HIRIYUR	11.88	11
10	NELAMANGALA	11	BASTIPURA	11.19	25
10	NELAMANGALA	11	BASTIPURA	11.19	24
10	NELAMANGALA	12	HOODY	11.19	22
10	NELAMANGALA	12	HOODY	11.19	23
10	NELAMANGALA	13	BIDADI	11.18	27
10	NELAMANGALA	13	BIDADI	11.18	27
13	BIDADI	14	SOMANAHALLI	11.18	30
13	BIDADI	14	SOMANAHALLI	11.18	31
10	NELAMANGALA	16	GOOTY	11.43	17
12	HOODY	15	KOLAR	11.75	12
12	HOODY	15	KOLAR	11.75	12
12	HOODY	16	GOOTY	11.56	14
5	JSW	18	BTPS	11.69	13
17	RTPS	18	BTPS	11.10	36
17	RTPS	16	GOOTY	11.11	35
17	RTPS	16	GOOTY	11.11	35
17	RTPS	4	GD HALLI	11.07	37
18	BTPS	6	HIRIYUR	11.32	19
18	BTPS	6	HIRIYUR	11.32	18
19	DUMMY19	17	RTPS	7.529	39
20	DUMMY20	17	RTPS	10.14	38
11	BASTIPURA	21	DUMMY21	11.90	9
11	BASTIUPRA	22	DUMMY22	11.90	8
15	KOLAR	23	DUMMY23	13.49	3
15	KOLAR	24	DUMMY24	12.61	6
17	RTPS	40	MEHABOOBNAGAR	13.03	4
1	KAIGA	2	NARENDRA	11.18	28

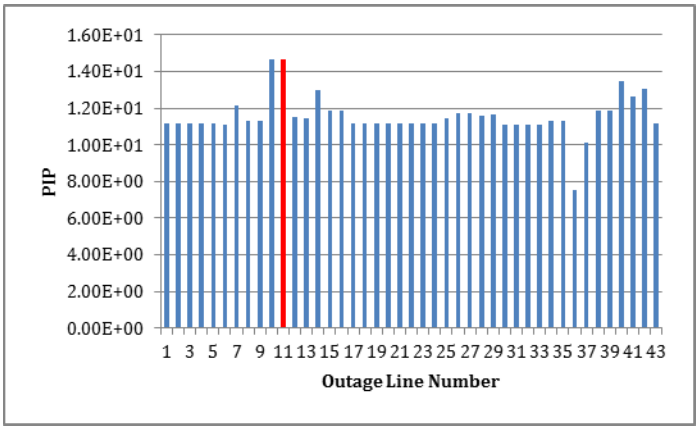

Fig. 4: Value of PIP for 400kV Karnataka Network (N–1 Contingency)

The contingencies have been ordered by their ranking where the most severe contingency is being ranked 1 and the least has been ranked 39. The variation of voltage performance index with their ranking has been shown in the Fig. 5. It is clear from the result of different PIV that the contingency number 38 which the line outage contingency corresponding to the line connected between buses (11-21) is the most severe contingency.

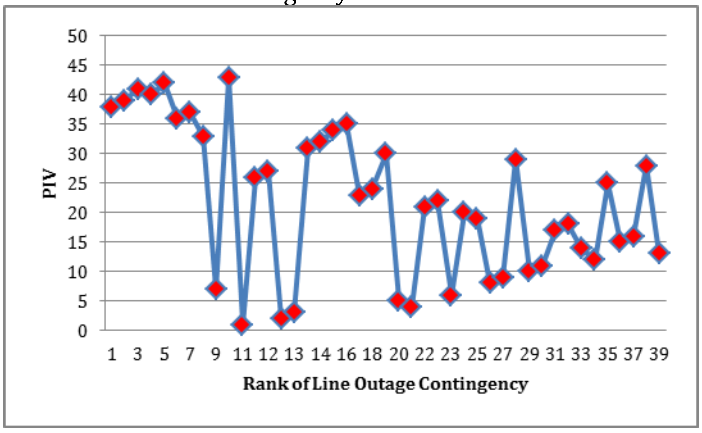

Fig. 5: Contingency Ranking and PIV of 400kV Karnataka Network (N–1 Contingency)

The variation of active power performance index with their ranking has been shown in the Fig. 6. It is clear from the result of different PIP that the contingency number 11 which the line outage contingency corresponding to the line connected between buses (7-8) is the most severe contingency.

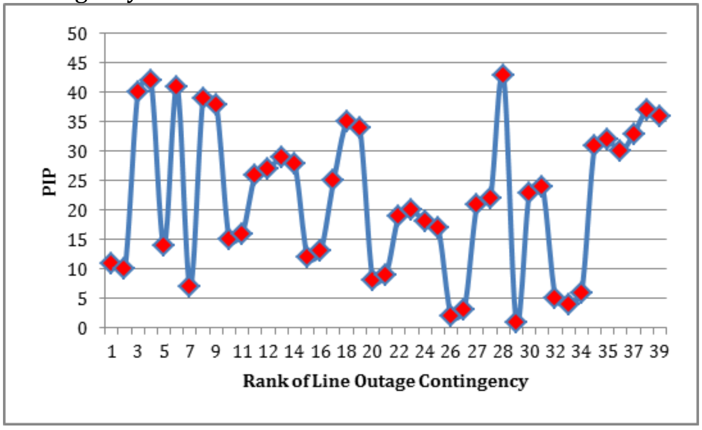

Fig. 6: Contingency Ranking and PIP of 400kV Karnataka Network (N–1 Contingency)

6. CONCLUSION

The method of contingency analysis and ranking using Fast Decoupled Load Flow method in this paper by using MiPower tool has been done. Since, the list of possible contingency cases is very large for 400kV KPTCL Bus system, hence the approach of contingency selection plays a very important role as it eliminates the large number of contingency cases and focuses on the most severe contingency case. From the results obtained it can be concluded that the calculation of performance indices gives a good measure about the severity of all the possible line contingencies occurring in the system. The indices with highest value reflect a severe case which has the highest potential to make the system parameters to go beyond their limits. That is from N-1 Contingency Result; it is clear that from different PI_V and PI_P that the contingency numbers 38 and 11 which are the line outage contingencies corresponding to the line connected between buses (11-21) and (7-8) respectively are the most severe contingencies. Hence, the most severe contingency case has been chosen from the list of various line contingencies.

RECOMMENDATION

Various FACTS devices can be used to avoid the above mentioned contingency problem.

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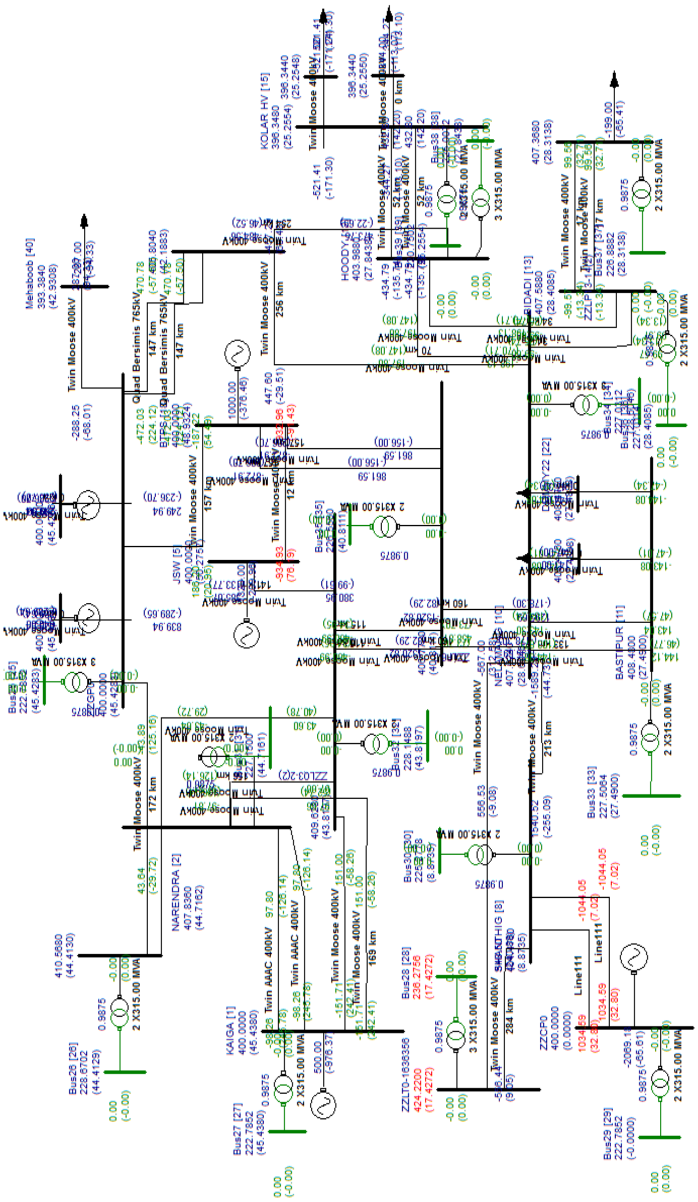

Fig. 7: 400kV KPTCL Bus System Drawn in MiPower