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Dynamic Load Modeling for KHUZESTAN Power System Voltage Stability Studies

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***Abstract*—** Based on the component approach, three kinds of dynamic load models, including a single –motor model, a two-motor model and composite load model have been developed for the stability studies of Khuzestan power system. The study results are presented in this paper. Voltage instability is a dynamic phenomenon and therefore requires dynamic representation of the power system components. Industrial loads contain a large fraction of induction machines. Several models of different complexity are available for the description investigations. This study evaluates the dynamic performances of several dynamic load models in combination with the dynamics of a load changing transformer. Case study is steel industrial substation in Khuzestan power systems.

***Keywords*—** Dynamic load, modeling, Voltage Stability.

I. INTRODUCTION

THE purpose of this paper is to report the development of dynamic load models and their applications to the voltage stability analysis of Khuzestan system.

Dynamic load models, as well as the phenomena of voltage instability, are of growing importance to the studies of power system dynamic [1]. If the load representation is not of sufficient accuracy, the simulation results will not correspond to the actual response of the load. This will affect the assessment of system stability limit [2].

Frequently, both power industry engineers and academic researchers study system stability and planning by utilizing static load models (i.e. constant impedance, constant current, constant power, and combinations of these models) to represent the relationship between power and voltage. Because these load models are static and time invariant, they are not sufficiently accurate to describe the load behaviors under various operation conditions. The uncertainty regarding load composition and the sufficiency of these static load models have been questioned in some publications [3]. However, the load behavior is mostly dynamic, with the real and reactive powers being changed at any instant of time [4]. For this reason, dynamic load models are considered. Previous studies [5] showed that close accuracy could be achieved by using a composite load model (dynamic + static) to represent the dynamic real reactive powers versus the voltage response of the load under typical faults. However, such a composite load model can only model the real power versus voltage response with better accuracy while the accuracy is not so satisfactory for the reactive power under a severe disturbance.

This paper consists of two parts. The first part describes the aggregation of dynamic load models by using both the LOADMOD program [6] and an Eigen value –based approach. The second part presents the voltage stability studies for Khuzestan power system with various load models that defined in next section.

II. THE DERIVATION OF DYNAMIC LOAD MODELS

In this paper, we utilize three types of dynamic load models which are summarized as following:

Model 1: A single – motor model is shown in figure 1. The parameters of this dynamic load model are determined from LOADMOD program [7] using the mixture data determined from Khuzestan power load buses. The mixture data and the estimated values of a single-motor model for the Khuzestan load are listed in Table I and Table II respectively.

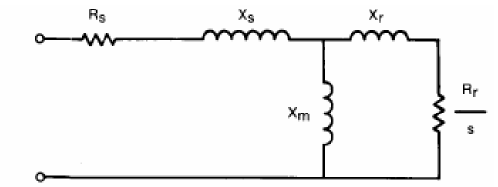

Fig. 1 The equivalent electric circuit of a single motor model

Model 2: A simple description of a two-motor model is shown in Fig. 2, the relevant equations for calculating electric parameters of the two –motor model have been developed and presented in [8]. The motor model have been developed and presented in the flow chart of Fig. 3. The estimated values of the two motors for the Khuzestan power load buses and the percentage of load composition are listed in Table III.

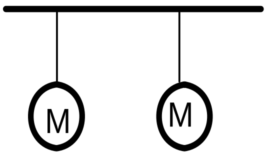

Fig. 2 Simple description of a two motor model

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TABLE I
LOAD CLASS MIX DATA FOR KHUZESTAN POWER SYSTEM

Area name	Reside (%)	Com. (%)	Lig (%)	Ind. (%)	Agr. (%)
AHWAZ	32	9	3	54	2
HAMIDIEH	58	19	8	8	7
MOLLA SANI	45	12	8	15	20
RAMHORMOZ	50	6	5	38	1
HAFTGEL	20	4	2	72	2
SHUSH	40	8	5	43	4
DEZFUL	65	15	5	7	8
BAGHMALEK	67	8	1	12	12
IZEH	50	19	8	18	5
SHUSHTAR	55	10	3	20	12

TABLE II
ESTIMATED VALUES OF A SINGLE MOTOR MODEL

	KORMA	SEPANTA	GOLESTAN	FOOLAD	DEZFUL
P0	69	62	51	520	30
Q0	32	31	25	176	15
Rs	0.04	.03	.06	0.02	0.06
Xs	0.1	.09	0.12	0.09	0.11
Rr	0.03	.02	.05	0.02	.04
Xr	0.13	0.13	0.1	0.16	0.1
Xm	2.89	3.12	2.55	3.25	2.6
h	0.74	0.84	0.55	0.95	0.57
A	0.81	0.91	0.61	0.94	0.65
B	0	0	0	0	0

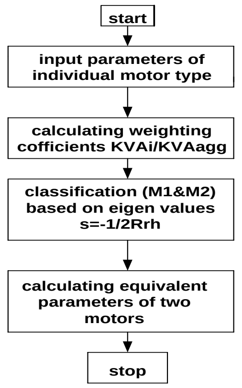

Fig. 3 Flow chart for motor separation based on Eigen values method

TABLE III
ESTIMATED VALUES OF A TWO MOTOR MODEL

	KORMA	SEPANTA	GOLESTAN	FOOLAD	DEZFUL
P0	69	62	51	520	30
Q0	32	31	25	176	15
Rs	0.03 0.08	0.02 0.06	0.05 0.10	0.01 0.04	0.05 0.12
Xs	0.1 0.15	.09 0.13	0.12 0.15	0.09 0.12	0.11 0.16
Rr	0.02 0.06	0.02 0.04	0.04 0.1	0.01 0.04	0.03 0.08
Xr	0.123 0.124	0.13 0.14	0.1 0.11	0.16 0.17	0.1 0.12
Xm	2.89 2.50	3.12 3.10	2.55 2.50	3.25 3.20	2.6 2.5
h	0.72 1.50	0.82 1.65	0.54 1.11	0.92 1.81	0.55 1.13
A	0.81 1.60	0.91 1.80	0.61 1.12	0.94 1.85	0.65 1.34
B	0 0	0 0	0 0	0 0	0 0

Model 3: A composite load model (dynamic static), shown in Fig. 4. The parameters of this composite model are determined from the LOADMOD program. The estimated values of a composite model for Khuzestan power system listed in Table IV.

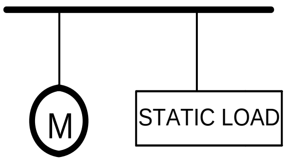

Fig. 4 Simple description of a composite model

III. POWER SYSTEM MODEL

Power system dynamic involve slow processes and action of control units such as LTC's, automatic voltage regulators, over –excitation limits, etc. Those devices do not necessarily have to be modeled in transient stability studies, but they can not be neglected in voltage stability studies. Time domain simulations need to be carried out in a long time frame, usually several minutes, to get insight into the physical mechanisms.

The following detailed models are implemented in the investigated case studies to allow accurate forecasting of power system dynamics concerning voltage stability.

TABLE IV
ESTIMATED VALUES OF A COMPOSITE MODEL

Static Parameter					
	KORMA	SEPANTA	GOLESTAN	FOOLAD	DEZFUL
P0	69	62	51	520	30
Q0	32	31	25	176	15
KPV1	1.83	1.80	1.84	1.69	1.83
KPV2	1.88	1.86	1.89	1.84	1.88
KQV1	-3.03	-2.99	-3.05	-1.27	-3.02
KQV2	2	2	2	2	2
KPF1	0	0	0	-1.02	0
KQF1	3.29	3.23	3.31	1.83	3.27
KQF2	1	1	1	1	1
Pa1	0.1	0.11	0.1	0.87	0.1
Pa2	0.9	0.89	0.9	0.13	0.9
Qa1	0.13	0.16	0.13	0.19	0.14
Qa2	0.87	0.84	0.87	0.81	0.86
Dynamic Parameter					
Rs	0.04	.03	.06	0.02	0.06
Xs	0.1	.09	0.12	0.09	0.11
Rr	0.03	.02	.05	0.02	.04
Xr	0.13	0.13	0.1	0.16	0.1
Xm	2.89	3.12	2.55	3.25	2.6
h	0.74	0.84	0.55	0.95	0.57
A	0.81	0.91	0.61	0.94	0.65
B	0	0	0	0	0

A. *Under Load Tap Changer Transformer*

Transformers with tap-changing facilities can be represented in simulation. Voltage on the transformer's secondary side is measured and compared with a reference voltage usually corresponding to the load flow result at rated conditions. A voltage deviation outside a dead-band margin initiates a tap-changer action. To avoid unnecessary actions, a time –delay of 30 s before the first change is implemented. Every subsequent tap change has a delay of 5 s leading to a typical dynamic ration following a deviation of secondary voltages as seen in Fig. 5.

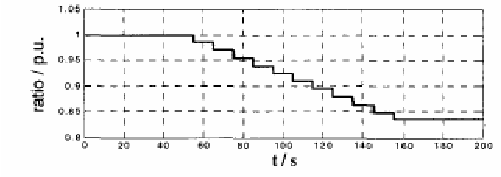

Fig. 5 Typical LTC transformer action

B. *Automatic Voltage Regulator with Over Excitation Limiter*

The Generators feeding bus of RAMIN power plant and ZERGAN power plant of the network is equipped with an excitation system of IEEE type DC1A including an automatic voltage regulator. Typical data for time constants and gain are chosen from [10]. An over-excitation limiter for thermal protection of the generator is implemented allowing a maximum field current of 2.5 pu for a short duration and a long term field current limit of 1.2 pu. The characteristic dynamic behavior of the field current due to an increased power demand is depicted in Fig. 6.

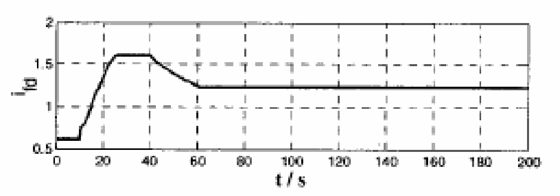

Fig. 6 Field current dynamics due to OXL

IV. LOAD MODELLING

In this investigation, steel industrial load connected to a 33 KV-bus is modeled assuming two integral parts. One part describes all static components of the load and the other part includes all dynamic components.

The dynamic part consists of an aggregate induction machine model whereas the static part is represented by an exponential-model [11]. The 33kV-bus is connected to a 230KV-bus and the LTC-transformer feeding the 33KV-bus form the high-voltage-bus is explicitly modeled. This leads to a load configuration as shown in figure 7.

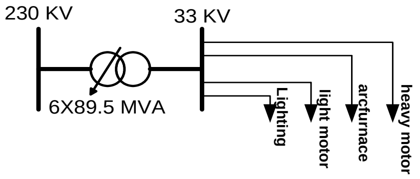

Fig. 7 Steel industrial load model in Khuzestan power system

V. CASE STUDIES

In this paper, modeling of all equipment and all dynamic simulations of the power system are carried out using the power system software package CYME [12]. This program is able to realize calculations of electromagnetic and electromechanical transient phenomena in time and frequency domain. Linear and non-linear elements can easily be described using this software. This offers great flexibility for the development of new dynamic models for all simulation purposes. After implementation load models, control parameters and disturbances must be defined.

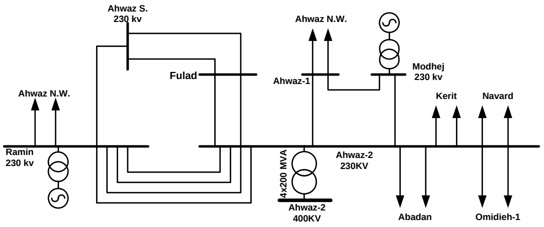

Fig. 8 a part of Khuzestan power system

Voltage stability investigations are carried out on the power system shown in figure 8. The system is mainly fed by a bulk network on bus of RAMIN and ZERGAN power plant. Power transfer takes place over a system of several transmission lines connected together .This leads to an interconnected network configuration, where the load is far a way located from the generating units. Generator on RAMIN bus is equipped with an automatic voltage regulator and an over-excitation limiter.

Steel industrial load is connected to bus FULAD of the power system. An LTC-Transformer connects the 230 kV – bus to the medium voltage bus of the industrial load. The disturbance consists of a short circuit in 230KV-bus in steel industrial load.

VI. SIMULATIONS

Different Load configurations are studied::A single – motor model *(Model 1)*, A simple description of a two-motor model (*Model 2*) and A composite load model (dynamic-static) *(Model)* used on FOLAD bus primarily consists of 520 MW active power with a total power factor of 0.9. The voltage on FULAD bus is 0.951 pu.

The responses of active and reactive power following the predefined short circuit are shown in Fig. 9 and Fig. 10, respectively. In all figures, power is given in pu on a 100 MVA-base and voltage is given in pu based on nominal voltage. The reduced power transmitted to the load leads to a reduced load bus voltage as seen in Fig. 11. The transients die out soon, and the increase of bus voltage is due to the AVR operation following a limitation of voltage by the OXL operation.

The reduced voltage initiate tap changer action that can be observed in a longer time scale. These delayed control processes need to be observed in voltage stability studies. However, with these load configurations, the system always remains stable and no voltage instability phenomena can be observed.

Since in time domain analysis, the distance to voltage instability can not be estimated, the dynamic state-change following the disturbance is visualized in the PV-plane. The static PV-curves relate the active power transferred to a bus to its bus voltage as given by a load flow calculation. Static PV-Curves for *AHWAZ2* bus are calculated for pre and post – disturbance conditions and are shown in Fig. 12.

The dynamic state-change of the three load configuration is included in this figure model comparison together the simplified models 1, 2 and 3. In the pre-fault configuration, system voltage and load power are situated in point A. Following the disturbance, the voltage on *AHWAZ 2 bus* drops and a fast transient state-change to point B takes place within a few seconds.

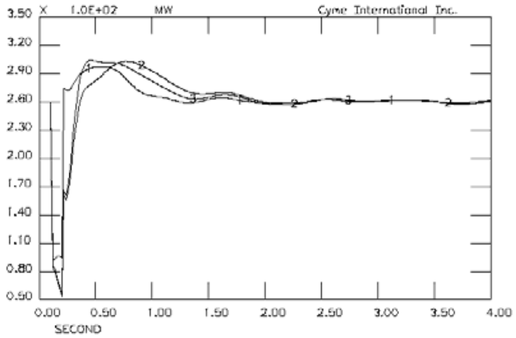

Fig. 9 Transient load responses, active power in FULAD bus

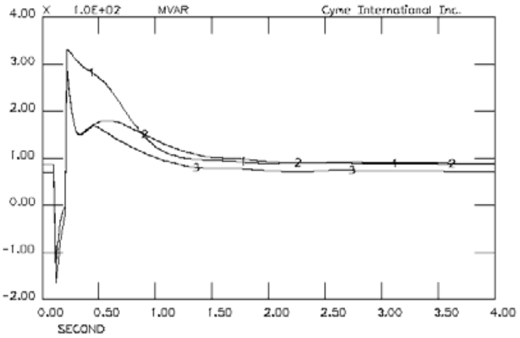

Fig. 10 Transient load responses, reactive power in FULAD

Bus

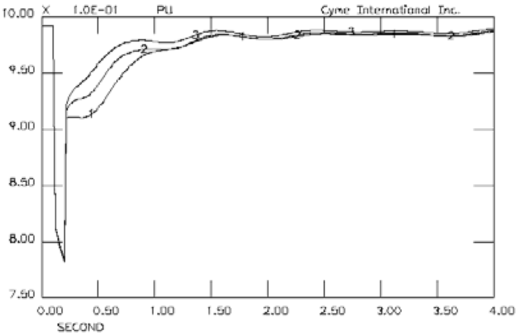

Fig. 11 Voltage on AHWAZ 2 bus (230 KV)

Due to slow controller actions of the AVR, reactive power support is given to the load bus and the operating voltage is increased. The new operating point C is reached. As it is shown in Fig. 11, between 10 ms s and 200ms, the action of the LTC-transformer takes place. This operation leads to an increase of second dray voltage and therefore to an increase of power absorption of the load. Due to this increasing load demand, voltage on *AHWAZ2 bus* decrease to its final value on point D. The simplified models A and B are also able reach point B after the disturbance, although they follow different trajectories as it is seen in Fig. 12. The dynamic state –change using model 3 does not match the final value obtained by the detailed modeling. The voltage drop predicted is too small compared with the other models. If, in a heavier loaded system, a simulation is carried out with model 3, voltage stability could be predicted, although the system becomes unstable. Model 3 is therefore not recommended for application in voltage stability investigation.

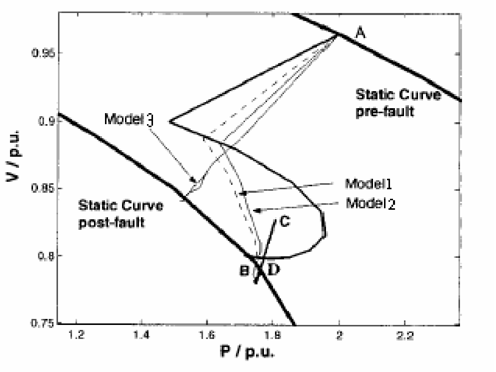

Fig. 12 Dynamic load responses as seen from AHWAZ2 bus

VII. CONCLUSION

In this paper, three different approaches of modeling loads with a high fraction of induction machines were carried out. three kinds of dynamic load models , including a single –motor model , a two-motor model and composite load model have been developed for the stability studies of Khuzestan power system..Compared simulations with together , it was found that the simplified models 1 and 2 are suitable for application in voltage stability studies , whereas model 3 does not capture the dynamic state-change adequately giving wrong predictions on voltage stability behavior .

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